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Expedient Repair Materials for Roadway Pavements

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March 2005

20050504 004

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Final report

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ABSTRACT:

Materials for expedient roadway pavement repairs must provide a trafficable repair in a minimal amount of time. Therefore, any repair material must be able to cure quickly and be easy to use.

There are a large number of proprietary cementitious rapid repair materials for both asphalt and concrete pavements. Three types of cementitious materials were used to make acceptable expedient repairs to an asphalt roadway. Trafficking showed that these materials were not flexible enough to provide durable repairs to flexible pavements in hot weather.

There are a number of proprietary asphalt based repair materials. These materials can generally be trafficked immediately after placement with some displacement, depending upon the loads. These products will gain more stability with time and with cooler temperatures. Repair materials using cut-back asphalts generally provide the best combination of workability and long-term storage under adverse conditions, particularly freezing temperatures. This study evaluated the asphalt repair materials for workability, strength using Marshall stability and triaxial testing, and durability in regards to cohesion and adhesion properties. The majority of repair materials use an open-graded mixture and the Marshall stability test is not appropriate for this type of gradation. The proprietary cold mixtures were all easier to apply and work with than the conventional cold mix. The products that advertised placement into wet holes all preformed well and provided equal performance in both wet and dry holes for the traffic and evaluation period used.

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Preface

This report describes the results of laboratory and field evaluations conducted by the Geotechnical and Structures Laboratory (GSL), U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS. The evaluation was sponsored by the Headquarters, U.S. Army Corps of Engineers, under the project AT40, "Upgrade and Sustainment of Theater Lines of Communication: Expedient Repair Materials."

This evaluation was conducted under the general supervision of Dr. David W. Pittman, Acting Director, GSL, and under the direct supervision of Dr. Albert J. Bush III, Chief, Engineering Systems and Materials Division (ESMD), and Mr. Don R. Alexander, Chief, Airfields and Pavements Branch. The report was written by Dr. James E. Shoenberger (deceased), Mr. Wayne D. Hodo, Dr. Charles A. Weiss, Jr., Dr. Philip G. Malone, and Dr. Toy S. Poole. Other ESMD staff members actively engaged in the implementation of the evaluation were Messrs. Roosevelt Felix, Jr., Quint Mason, Timothy McCaffrey, and Herbert McKnight.

COL James R. Rowan, EN, was the Commander and Executive Director of ERDC and Dr. James R. Houston was the Director.

1 Introduction

Background

U.S. Army operation requirements are currently focusing on increasing the ability of force maneuver support. The term maneuver support can be defined as the means to gain and maintain freedom of maneuver and force protection within a theater of operations. In particular, the focus is to establish, sustain, and secure objective force lines of communication (LOC). Future forces will put a premium on mobility, and the network of ground LOCs in the theater will be a critical component of theater campaigns and tactical operations. Ground LOCs will be the foundation of force movement for force sustainment and will link the majority of operational forces to within shifting areas of operations.

Previous work has been done to evaluate the requirements involved in the deployment of forces from their bases into a theater of operations. However, to provide for maximization of the mobility and force protection of the arriving forces, information and procedures are also required in a variety of areas to maintain the transportation infrastructure within the area of operations. Conventional repair procedures often require the use of large and specialized construction equipment and tightly specified materials, and the length of time of repairs is not critical. These procedures often require a substantial amount of mobilization resources to transport the men and equipment needed to achieve the repairs necessary for maintaining the LOC. In many instances, the mobilization resources are not available, and conventional equipment and materials are not available locally. In maximizing an objective force's LOC, time is a critical factor. Reducing the time required for each repair and increasing the length of time between repair procedures will greatly increase the objective force's LOC.

Objective

The objective of this study is to investigate materials and methods with a reduced logistics footprint to achieve rapid repair for the sustainment of theater roadways. Material and method requirements were investigated with the goal of reduced material and time requirements when compared with standard repair techniques used to maintain roadways. The reductions in time could include both installation time and curing requirements.

Scope

The overall scope of this study was to identify material types available and their material properties for repair of both asphalt and portland cement concrete pavements. The repair requirements for unsurfaced roads were not addressed in this study. The distresses considered were related to load or environmental factors and are not related to military actions (i.e., bomb craters).

2 Repair Parameters

General

The goal is to meet expedient repair requirements for roadway pavements while reducing the logistics and material requirements often associated with conventional methods. The term expedient, as it is used in this study, is defined by Webster as “suitable for achieving a particular end; a means to an end or to meet a need.” The selection of the expedient repair materials for roadways may result in the sacrifice of some long-term durability for a decrease in time and material requirements. This possible reduction in durability is necessary to provide the military immediate and as close to continuous on-ground LOCs as possible. Using the term expedient to describe repair materials for roadway repairs is based on the immediate tactical situation as well as factors such as urgency and availability of manpower, materials, and equipment. Current and future emphasis for the use of expedient repair materials is to provide a suitable repair while using the absolute minimum resources required to perform the mission.

A reduction in the logistic footprint can be achieved by reducing the weight or volume of materials required for repair and by increasing the durability of the repair. This can be achieved by developing higher strength materials, resulting in thinner sections that can carry the required loads. Another method would be through the use of locally available materials, often to extend the expedient repair materials. The nonavailability of gravel or other standard aggregates has been a severe problem during many military deployments. The ability to use nonstandard or marginal aggregates as part of the repair materials, without a decrease in durability, would result in the desired reduction of the logistic footprint.

The ideal repair material could be prepared and placed in any weather by personnel without extensive training, be no more toxic or dangerous than and have a minimum performance equal to conventional pavement repair materials, and have a minimum shelf life of several years. This material probably does not exist, but it is possible that a combination of materials can be used to meet the same requirements. The goal is to develop a few materials that can be used in combination to meet the requirements for repairs at any time, anywhere in the world.

Concrete repair materials are formed through a chemical process in which various mixture components combine to form a hardened matrix. Concrete repair materials often use sand-sized aggregate particles to produce a mortar mixture for small-volume repairs. For larger volume repairs, this mixture can be extended with the addition of coarse aggregate to produce a concrete mixture.

The asphalt cement binder used to make repair materials is a thermoplastic material that increases in viscosity as the temperature decreases. This asphalt cement coats the aggregate particles and holds them together after cooling. Asphalt cement can be made fluid at ambient temperatures, thereby eliminating the need for heating, by either cutting or diluting it with petroleum-based solvent materials or by emulsifying it with water. Cutbacks are asphalt cements that have been diluted or cut with a petroleum solvent (i.e., gasoline, kerosene, or oil). Emulsions are asphalt cements that have been emulsified or contained in an aqueous solution.

Design Failure Criteria (Thresholds for Reconstruction)

Roadway pavements requiring reconstruction could be constructed as either rigid (portland cement concrete, PCC) or flexible (hot-mix asphalt, HMA) pavements. The roadways could also be classified as unfinished (i.e., gravel-surfaced roads). The thresholds normally associated with failure of the pavement design for the respective type of road surfacing are given below.

- a. *PCC pavement.* Pavement failure of a slab occurs when at least 50 percent of the slabs in the traffic area have a crack that divides the slabs into two or more pieces.
- b. *HMA pavement.* HMA surfaces can be considered to have failed when the rut depth exceeds 25 mm (1 in.).

Thresholds for Maintenance and Repair

The type and amount of distress that a pavement surface can develop before maintenance and repair is required will vary with the type and number of vehicles trafficking the road. The distress levels listed above consider only the failure method used for design of the pavement. At the levels of distress listed above for the various surfaces, passage would still be possible for most types of vehicles; however, these levels could limit the speed at which a vehicle would traverse the road.

There are distresses, other than those considered for design criteria, that must be considered for maintenance and repair. The major distresses for PCC pavement include cracking, spalling, and faulting. For HMA pavements the major distresses include cracking (due to both traffic loading and environmental conditions), shearing movement (rutting, shoving, and corrugation), surface distress (raveling and weathering), and potholes. For unsurfaced roads, the major distresses include improper grade and smoothness, potholes, and ruts.

The pavement condition index (PCI) is a method used to define the current condition of a pavement surface in regard to various distress types and levels. Minimum PCI levels for airfield pavements are ≥ 70 for runways, ≥ 60 for primary taxiways, and ≥ 55 for aprons and secondary taxiways. For roadways, the minimum PCI levels are 60 for primary roads, 50 for secondary roads, and 45 for tertiary roads.

Evaluation Parameters

Field placement parameters were established to provide a framework for comparison of the various asphalt repair materials (Table 1). The evaluation parameters include the environmental conditions of temperature and moisture, equipment, and aggregate. Other parameters such as cost, safety, and shelf life are important, although they may not be controlling factors in material selection.

Table 1		
User Parameters for Repair		
Evaluation Parameter	Range of Placement Parameters	
	Minimum	Maximum
Pavement temperature	Below freezing	71 °C (160 °F)
Air temperature	Below freezing	≈49 °C (120 °F)
Pavement moisture	Dry	Under water
Air moisture	Dry (low humidity)	Rain (100% humidity)
Aggregate	Low quality, uncrushed	High quality, crushed & graded
Equipment	Hand tools	Specialized mechanized equip.

Temperature

The ambient temperature at the time of placement of materials is of critical importance to their placement. The temperature of the pavement upon which the repair is to be made can vary from below zero (point of freezing) to over 60 °C (140 °F). Air temperatures can also vary from below zero to occasionally over 49 °C (120 °F). Variations in air temperature are mimicked by the pavement, although somewhat delayed and with less overall change, except for solar heating. The effect of the sun shining on a pavement surface often results in the pavement temperature greatly exceeding the air temperature, especially for darker colored surfaces. Dark pavement surfaces (HMA), in some locations, can reach temperatures approaching 71 °C (160 °F) on hot sunny days. Considering solar heating, the largest change in temperatures occurs in about an 8-hr time span, from lows at about 0500 hr to highs about 1400 hr (Shoenberger 2001).

Conventional construction practices normally require temperatures of about 7 °C (45 °F) and rising for asphalt materials and range from about 7 to 30 °C (45 to 85 °F) for concrete materials. These temperature limits show that working with many conventional materials at extremes of either high or low temperatures can cause problems. Expedient repair materials need to have the ability to be applied at temperatures outside of these ranges.

Moisture

The amount of moisture or humidity present at the time of placement of materials is of critical importance to their performance. The amount of humidity in the air will vary with the geographical region, the time of year, and local weather occurrences. Humidity levels from very low to around 100 percent will

have a considerable effect on the rate of evaporation of moisture and other volatiles. Repairs attempted during rainfall and immediately after rainfall are greatly affected by the excess moisture. Conventional repair materials require a dry surface or, at most, only a slightly wetted surface in order to bond to the existing surface. Conventional repair materials cannot be placed during rainfall. Compaction of conventional materials is difficult when excess water is present because the water results in excess pore water pressure to counteract the compaction effort. Hot mixtures have the same problem and will quickly cool due to heat loss from the moisture. Hard rains will flood repair areas and require repair materials to displace the water. Mixtures can be compacted in water only if they are cohesive enough to displace and not absorb the water prior to compaction. Chemically setting or curing materials, such as portland cement and other concrete materials, can be placed while displacing the water, provided that they are designed for this purpose.

Cost

The cost of each repair material evaluated as part of this study is reported in the Fact Sheets presented in Appendix A. The cost of the material, while not unimportant, is not as critical a factor as it would be for conventional repair applications. The overall cost of using the material within a theater of operations would include the purchase price plus the logistics cost of shipping the materials. In many situations, the material cost is not extravagant; the logistics cost would constitute the largest percentage of the overall cost. This is certainly true when the higher cost material results in increased operation capability.

Safety

The safety concerns of each material, relative to handling, mixing, and placement, are important considerations. Safety concerns are reported based on laboratory and field experience and information available from the manufacturer's material safety data sheet.

Shelf life

The shelf life, as provided by the manufacturer, is reported for each material. The shelf life of a material is important to the military because of the need to stockpile materials for availability with minimal warning of impending need. When possible, the overall effect of performance on using expired materials will be reported. The shelf life of many materials is dependent upon the conditions existing during storage; generally, materials will last longer if stored under controlled conditions rather than out in the elements. Some materials are greatly affected by temperature or moisture extremes, while some are affected only by extreme conditions in one direction. For example, a cutback asphalt mixture will not be greatly affected by long periods of extreme cold, but it will lose overall workability if exposed to high temperatures for long periods of time.

Equipment

The availability of equipment, in various types and amounts, can have a significant effect on what methods and materials can be used for repairs. In situations where no machines or specialized mechanized construction equipment is available, the possibilities are limited and not all maintenance options can be considered. Therefore, when equipment is not available, only repairs can be considered, and the size of these is governed by the number of personnel available. In these situations, the types of materials that can be used are also limited. Materials that require heating or large mixers or that cannot be placed by hand can be used only when satisfactory equipment is available. When equipment is not available locally, repair practices may have to be considered in regard to initial and long-duration phases. In the initial phase, construction equipment is severely limited or not available, and only limited repairs are possible. After a period of time, it is anticipated that more mechanized equipment will become available, making possible more complex maintenance and repair procedures with a wider range of repair materials.

Aggregate

Aggregate is a critical item in most repairs, especially when the volume of the repair is large. Recent military operations have shown that the availability of high-quality aggregate in many locations is severely limited. Conventional aggregate used for both asphalt and concrete repair materials have requirements for relatively clean, hard, angular, and durable particles within a desired gradation band. Even in areas with ample stone or rock resources, unless crushers or washers are available, sufficient quantities of high-quality aggregates will not be available. Gravel may be available locally, but the quality or consistency is often unknown. A portable aggregate crushing plant would be a useful piece of equipment in establishing a stable LOC. A crushing plant would also require equipment and accessories for supplying parent rock, processing, and delivering the crushed aggregate. The amount of processing could be minimal—using only what is crushed, or it could be screened and gradations controlled. Particular gradations provide for optimum use of the cementing or binding materials; however, nonstandard gradations could be used for expedient applications.

The nonavailability of aggregates meeting standard requirements provides an emphasis for investigating the use of lower quality or marginal aggregates. The use and the effect of marginal materials for asphalt and portland cement concrete has previously been investigated for the construction of pavements (Grau 1979; Rollings 1988; Ahlrich 1997a, 1997b). These investigations generally found that some variation from specified requirements could be accomplished with only minimal decreases in performance; however, varying too far from established requirements would cause substantial decreases in performance. The difficulty of using these materials arises in knowing how far variations can be allowed without a substantial decrease in performance. Often, local conditions could affect performance, which would require engineering judgment to prevent failures.

3 Concrete Materials

Material Types

The need for rapid pavement repair necessitates the use of fast-setting or rapid-hardening cementitious materials. The terms fast-setting or rapid-hardening vary somewhat between manufacturers and are often not well defined. Generally, they include materials that achieve an initial set in less than 1 hr and a minimum compressive strength of 3.5 MPa (500 psi) within 3 hr. A listing of some rapid-hardening cementitious materials is given as Appendix B. The following is a list of the some of the available types of rapid-hardening cements:

- a.* Magnesium-phosphate cement.
- b.* High-alumina cement.
- c.* Regulated-set portland cement.
- d.* Gypsum cement.
- e.* Special blended cements.
- f.* Type III portland cement with accelerating admixtures.
- g.* Polymer cements.
 - (1) Epoxies.
 - (2) Methacrylates.
 - (3) Polyesters.
 - (4) Urethanes.
- h.* Proprietary materials: high waste.

Magnesium-phosphate cements are a blend of materials that react with water to form a rapid-hardening concrete. This cement is available in one-component systems, in which both are in powder form and water is added to form the concrete. Also available is a two-component system, in which a magnesium powder

can be combined with phosphate in an aqueous solution. These cements can be extended with aggregate, and several manufacturers produce both hot- and cold-weather formulations.

High-alumina cements have as their main component monocalcium aluminate ($\text{CaO} \cdot \text{Al}_2\text{O}_3$). The lime and alumina make up about 80 percent of the cement in roughly equal parts. While this cement achieves a high early strength, it has a relatively long initial set time followed quickly by the final set. This cement is commonly used in high-temperature (refractory) applications.

Regulated-set portland cements are a mixture of a portland cement and calcium fluoro-aluminate ($\text{C}_{11}\text{A}_7 \cdot \text{CaF}_2$). This cement provides high early strengths and rapid set times that can be regulated with admixtures.

Gypsum cement has calcium sulfate hemihydrate ($\text{CaSO}_4 \cdot 1/2 \text{H}_2\text{O}$) as its main ingredient. This cement has a very fast initial set and high early strength. The durability, abrasion resistance, and fuel resistance of this cement are low.

Special blended cements are proprietary materials that contain portland cement and other materials. Among the available rapid-hardening cements, these blended cements are generally the least expensive and simple to mix.

Type III portland cement, with accelerating admixtures, is a mixture of rapid-hardening cement and accelerating admixtures. The admixtures commonly used include gypsum, calcium chloride, calcium nitrate, and various carbonates. These cements achieve high early strengths and good durability, although they have relatively high heat of hydration and shrinkage.

Polymer cements are organic in nature and are produced by combining two or three liquid components during mixing. These monomer components can be polymerized with the addition of an aggregate into a polymer concrete. The polymerized monomer (synthetic resin) replaces the hydraulic cement as the bonding agent for the aggregates. Types of polymer cements include epoxies, methacrylates, polyesters, and urethanes. Polymer cements are good for expedient construction in that they are very versatile in set time and strength gain, have high adhesion properties and low shrinkage, and are relatively durable. However, they are generally expensive, relatively difficult to mix, have thermal properties different from conventional PCC, and can be a safety hazard for workmen.

Proprietary materials cover a wide range of fast-setting materials that do not fit into one of the previously listed categories. One group of this type of material contains at least some amount of waste material, usually fly ash.

Aggregate

The rapid-hardening repair materials used for concrete pavement in most cases will use aggregate to provide the necessary volume of repair material.

Aggregate can also provide greater economy, decreased thermal movement and, often, increased strength. The maximum size of the aggregate will vary with the size and depth of the area to be repaired. Generally, clean, coarse aggregate is all that is required.

4 Hot-Mix Asphalt (HMA) Pavement

Material Types

Hot-mix asphalt is used to construct pavements because heating the asphalt binder and aggregates prior to mixing is the most economical method to get proper coating and achieve the highest degree of compaction. Producing the same material for repairs requires a substantial investment in equipment and material, when satisfactory HMA cannot be purchased locally. The requirement for rapid repairs, coupled with the need for a reduced logistics footprint, increases the benefit of using a material that does not require heating. The major limitation of using cold asphalt mixtures is that they cannot be compacted to achieve the level of compaction of mixtures that are heated. However, with available additives, cold patch materials have been developed that are capable of durability that approaches that of HMA. A listing of some asphalt repair materials is given in Appendix C. The following is a list of available types of asphalt binder materials:

- a. Cutback.
- b. Emulsion.
- c. Proprietary products.

Cutback asphalts have historically been used as the binder for cold-mix asphalt patches. Cutbacks can be combined with well-graded blends of aggregates to produce dense asphalt pavement patches. The cutbacks used can be classified by type as either medium curing (MC) or slow curing (SC), as defined in ASTM D 2027 and D 2026, respectively. The particular grades of each type recommended for applications of immediate use in repairs include MC-250, MC-800, and SC-800. The same grades are recommended for applications of stockpiling with the addition of SC-250 (Asphalt Institute 1997). The shelf life of a cutback is practically unlimited, provided it is kept in a sealed container.

Emulsified asphalts are widely used in the repair of asphalt pavements. In an emulsion, the asphalt binder is suspended in an aqueous solution. This is an economical and environmentally acceptable method of obtaining asphalt cement in a workable consistency at ambient temperatures. A limitation of emulsions is the relatively short time they take to break and cure. Therefore, only slow-setting

emulsions should be used for cold mixes, and they should be used immediately and not stockpiled. This would include grades SS-1, SS-1h, CSS-1, and CSS-1h, where the "C" stands for cationic, and the "h" indicates an emulsion made from harder (higher viscosity) asphalt cement (Asphalt Institute 1997). Depending upon storage conditions, the shelf life of a typical asphalt cement emulsion is limited to between 6 months and, perhaps, 1 year. There are colloid asphalt emulsions that are more stable and will have a possible shelf life of several years.

Proprietary product manufacturers generally start with a cutback or an emulsion and then add some type of antistripping agent, polymer, or fiber. These materials are added to improve the strength, bonding, and durability of the repair material. Proprietary materials are usually available in ready-to-apply containers, sometimes varying from small bags or buckets to large containers. Some proprietary material manufacturers also sell the binder itself, which can be combined with suitable aggregates in the area it is to be applied.

A few products that are available for repair of HMA pavements do not contain any asphalt binder material. These materials are generally rigid materials that have low enough modulus values to provide some compatibility with the surrounding HMA pavement. Nonasphalt binders are not susceptible to the large changes in modulus values that occur with asphalt binders during changes in temperature. The modulus value of a HMA pavement can decrease by a factor of 10 as temperatures change from near freezing to 60 °C (140 °F) or above.

Aggregate

The materials used for repair of asphalt pavement generally include aggregate as part of the mixture. The size of the aggregate will vary with the depth of the pavement to be repaired. Most repair materials contain aggregates that have a maximum aggregate particle size of less than 12.5 mm (0.5 in.). This allows the patching material to be placed in thin layers of about 25 mm (1 in.).

The grading of the aggregate can have an effect on the performance of the cold patch material. Dense-graded aggregates are used to provide a stable, low void, and relatively waterproof pavement structure. Open-graded aggregates, when properly confined, can be stable and will generally be more porous than dense-graded aggregate structures. Compared with dense-graded asphalt mixtures, open-graded asphalt mixtures are normally more workable when temperatures are at or below freezing. In most instances, a dense-graded asphalt mixture would perform well at warm and hot temperatures, but an open-graded asphalt mixture is required for satisfactory workability at freezing temperatures.

Asphalt Materials Evaluation

Using the review of asphalt repair materials, 12 products were eventually obtained (Table 2). Samples of these products were either provided by the manufacturers or purchased for this study. The products that came in a bag or pail were prepackaged in that form. The products that were not prepackaged came in buckets from various points of manufacture from around the country. Appendix A contains fact sheets on each of these materials, based on information provided by the manufacturers.

Table 2 Asphalt Repair Materials Evaluated in Laboratory			
Material	Container	Binder Type	Type of Gradation¹
Cold Patch (Cold Weather)	18.9-L (5-gal) buckets	Cutback	Open
Cold Patch (Hot Weather)	18.9-L (5-gal) buckets	Cutback	Open
DuraPave	18.9-L (5-gal) buckets	Emulsion	Dense
ENVIROPATCH	18.9-L (5-gal) buckets	Inverted emulsion	Open
EZ Pave ²	18.9-L (5-gal) buckets	Emulsion	Dense
EZ Street	15.9-kg (35-lb) bags	Cutback	Dense
Instant Road Repair	22.7-kg (50-lb) pails	Cutback	Dense
Optimix	18.9-L (5-gal) buckets	Cutback	Open
Perma-Patch	27.2-kg (60-lb) bags	Cutback	Open
QPR-2000	22.7-kg (50-lb) bags	Cutback	Open
Sylcrete-EV	15.1-L (4-gal) buckets	Cutback	Open
UPM (Spring & Fall Grade)	22.7-kg (50-lb) bags	Cutback	Open
¹ The term "dense graded" could also be considered as well graded; the aggregate is spread over a series of sieve sizes.			
² EZ Pave is a cold-mix paving mixture and not a patching material.			

A laboratory evaluation program for the asphalt repair materials was developed to consider the workability, strength, and durability characteristics of the repair materials (Table 3). The materials were evaluated in the laboratory considering a wide range of conditions expected in the field, as listed in Table 1. As part of the evaluation of the obtained products, the gradation and binder content of each were determined (Tables 4a and 4b). The penetration and viscosity values of

Table 3 Asphalt Repair Materials Test Plan		
Material Property	Test Method	Test Standard - ASTM
Workability	Workability test	D 6704
Strength	Marshall	D 1559
	Triaxial	Detailed in text (page 19)
Durability	Cohesion	
	Adhesion	
Binder content	Extraction	D 2172
Max. specific gravity	Theor. max. density	D 2041
Bulk specific gravity	Marshall sample	D 2726
Recovered binder	Penetration	D5
	Viscosity	D 2171

Table 4a
Gradation, Cohesion, and Adhesion Properties of Test Materials

Material	Control	Cold Patch (Cold Weather)	Cold Patch (Hot Weather)	DuraPave	ENVIROPATCH	EZ Pave	EZ Street
19.0 (3/4)						97.5	
12.5 (1/2)	100	100			100	75.1	
9.5 (3/8)	86	99.7	100		98.3	59.8	100
4.75 (No. 4)	66	42.9	54.7	100	42.8	36.9	78.7
2.36 (No. 8)	53	9.2	13.3	94.3	8.6	22.8	28.1
1.18 (No. 16)	41	8.2	11.6	72.7	1.3	15.4	17.0
0.6 (No. 30)	31	7.7	10.7	51.6	1.2	11.5	12.2
0.3 (No. 50)	21	5.9	8.0	31.4	1.1	9.0	9.3
0.15 (No. 100)	13	2.5	3.6	19.1	1.0	7.2	5.7
0.075 (No. 200)	4.5	1.4	2.67	12.6	0.96	5.9	3.7
Binder content	5.2	3.0	3.9	6.05	2.3	4.24	4.19
Cohesion ¹	94.3	64.5	---	44.5	62.1	54.3	96.7
	93.6	99.4	---	47.3	87.7	67.8	96.9
	91.9	98.4	---	---	69.9	69.5	95.9
Average	93	87	---	46	73	64	97
Adhesion, ² sec	0	5	---	120	11 (C)	33	29
	0	7	---	120	1	4	3
	0	7	---	---	2	14	---
Average	0 ³	6	---	120	5	17	16

¹ Reported value is retained percentage (original mass divided by final mass).

² Time to separation of cold patch material and type of failure, which was adhesive in all cases except that marked Cohesive (C).

³ Specimens fell apart during extrusion from the mold.

Table 4b
Gradation, Cohesion, and Adhesion Properties of Test Materials

Material	Instant RR	Optimix	Perma-Patch	QPR-2000	Sylcrete-EV	UPM
19.0 (3/4)					100	
12.5 (1/2)	100	100			99.4	
9.5 (3/8)	99.7	96.2	100	100	94.5	100
4.75 (No. 4)	69.7	34.9	84.8	39.7	45.6	98.1
2.36 (No. 8)	33.4	9.1	21.8	5.4	17.9	27.7
1.18 (No. 16)	20.9	5.4	6.9	3.7	9.6	7.6
0.6 (No. 30)	14.2	4.0	4.0	2.9	6.9	4.9
0.3 (No. 50)	10.2	3.4	3.5	2.3	5.8	4.1
0.15 (No. 100)	7.2	3.0	3.3	1.6	5.2	3.4
0.075 (No. 200)	6.1	2.8	3.2	1.2	4.8	2.9
Binder content	4.9	3.8	2.8	3.0	4.0	4.04
Cohesion ¹	100	100	100	93.1	100	100
	100	100	99.9	94.0	100	99.9
	100	100	99.7	91.8	100	100
Average	100	100	100	93	100	100
Adhesion ²	16	2	3	3	8	6
	4	3	14	2	3	5
	4	4	12	2	3	2
Average		3	10	2	5	4

¹ Reported value is retained percentage (original mass divided by final mass).

² Time to separation of cold patch material; type of failure was adhesive in all cases.

the recovered binders are given in Table 5. The results of this laboratory testing were later used to select a reasonable number of materials for a field evaluation.

Table 5
Binder Properties of Recovered Asphalt¹

Cold-Mix Material	Penetration, 0.1 mm	Viscosity, ² cSt
Cold Patch (Cold Weather)	56	683
Cold Patch (Hot Weather)	7	— ³
DuraPave	6	180,000 ³
ENVIROPATCH	6	5,622
EZ Pave	13	9,012
EZ Street	24	2,894
Instant Road Repair	40	345
Optimix	20	1,270
Perma-Patch	25	4,153
QPR-2000	12	3,000
Sylcrete EV	27	675
UPM	27	1,250

¹ ASTM D 2172 (Test Method A).

² ASTM D 2170 (Kinematic Viscosity at 135 °C (275 °F)). Values expressed in centistokes (cSt).

³ Very stiff; would not flow in largest tube.

Workability

Workability, regarding cold-mix materials, can be considered as the amount of effort required to properly construct a repair with the mixture into the pavement. This repair procedure includes placing the material in the void and compacting it to the desired density. Various methods of defining workability have been used, including the subjective estimate of effort involved in penetrating a stockpile of mixture with a shovel or other object, or using conventional asphalt mixture test equipment to produce a parameter relating to workability.

Workability is currently defined in ASTM D 6704 (ASTM 2002) as *the average maximum resistance to penetration by a designated penetrometer into a compacted asphalt cold mix that is confined in a designated box*. The test method D 6704 was used to evaluate the workability of each of the cold-mix materials (Figures 1 and 2). The results of this testing are given in Table 6.

Strength

The strength of a mixture is important because of the traffic loads that it may be required to carry. The strength of a mixture can be measured in many ways, with Marshall stability being the most common for asphalt paving materials. Another method of measuring the strength and even the workability of the various materials is to observe their behavior during a triaxial test. Both unconfined and confined tests were conducted.

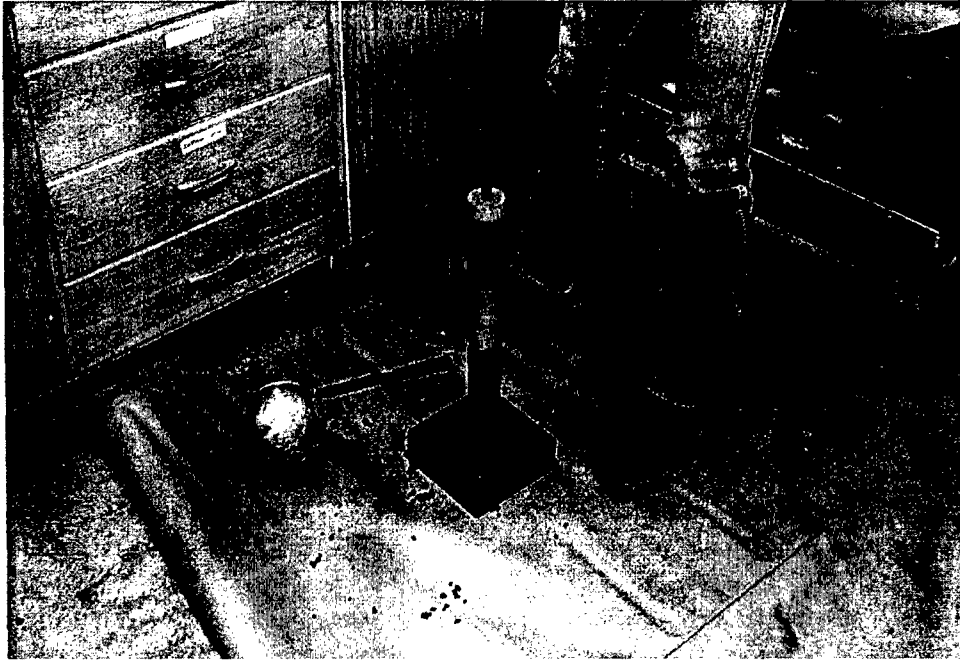


Figure 1. Compacting cold mix into workability test mold

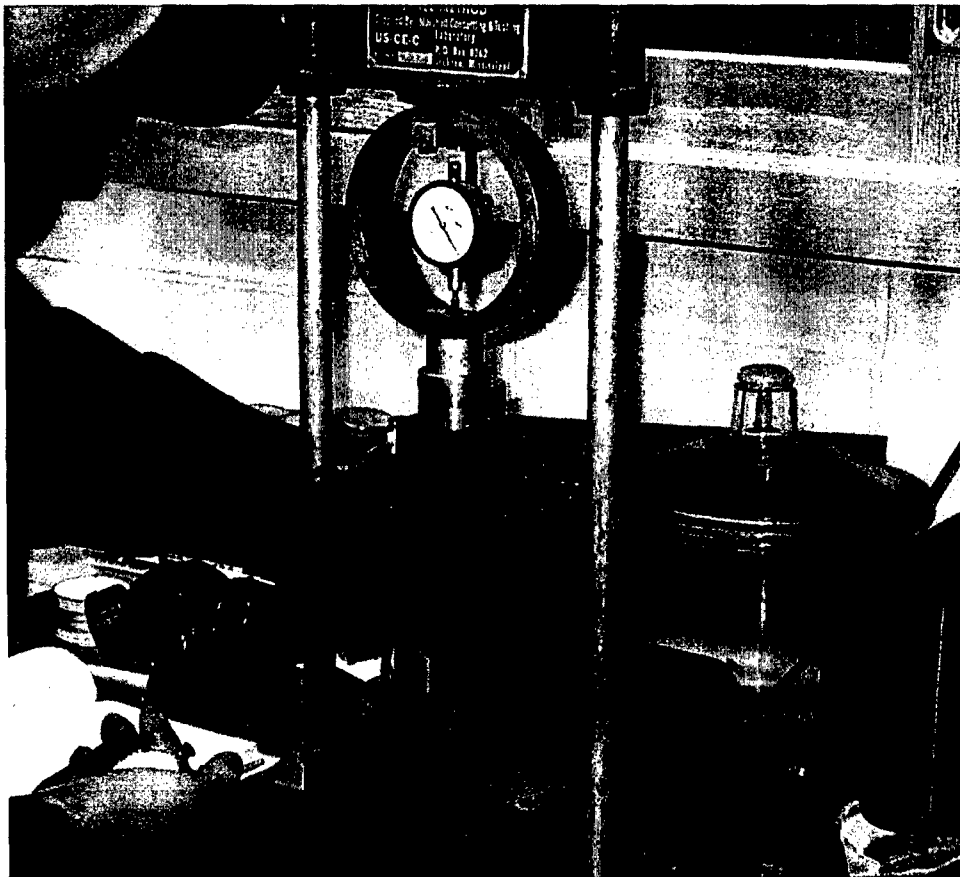


Figure 2. Using Marshall device to perform workability test

Table 6 Results of Workability Testing						
Material	Spec. No.	Specimen Mass, kg (lb)	Workability, N (psi)	Avg. Workability	Temperature ¹ Range, °C	Remarks
Cold Patch (Cold Weather)	1	2098.7 (5.62)	1.50 (338)	1.63 (367)	-22 to -1	Sticky; difficult to compact
	2	2119.8 (5.68)	1.83 (411)			
	3	2071.1 (5.55)	1.57 (353)			
Cold Patch (Hot Weather)	1	1935.9 (5.19)	2.08 (469)	2.06 (464)	-22 to -1	Sticky; difficult to compact
	2	1913.0 (5.13)	1.89 (425)			
	3	1956.8 (5.24)	2.21 (497)			
DuraPave	1	1723.7 (4.62)	6.15 (1382)	6.45 (1450)	-1 to 21	Sandlike, dry; compacts easily
	2	1734.8 (4.65)	6.34 (1426)			
	3	1741.4 (4.67)	6.86 (1542)			
ENVIROPATCH	1	2021.1 (5.41)	2.97 (668)	3.35 (754)	-12 to 10	Compacts somewhat easily
	2	2043.0 (5.47)	3.48 (782)			
	3	2066.8 (5.54)	3.60 (810)			
EZ Pave ²	1	1995.8 (5.35)	11.83 (2659)	10.26 (2307)	10 to 32	Compacts easily
	2	2046.9 (5.48)	9.19 (2066)			
	3	1971.2 (5.28)	9.77 (2196)			
EZ Street	1	1707.5 (4.57)	2.34 (526)	2.27 (511)	-12 to 10	Sticky; difficult to compact
	2	1727.8 (4.63)	2.53 (569)			
	3	1651.8 (4.43)	1.96 (440)			
Instant Road Repair	1	1836.6 (4.92)	3.67 (824)	4.36 (981)	-12 to 10	Stiff at ambient temperature
	2	1842.2 (4.94)	4.17 (938)			
	3	1738.0 (4.66)	5.25 (1181)			
Optimix	1	1885.0 (5.05)	6.41 (1440)	6.13 (1378)	-1 to 21	Excess water in container
	2	1813.3 (4.86)	6.02 (1354)			
	3	1915.6 (5.13)	5.96 (1339)			
Perma-Patch	1	2046.2 (5.48)	1.24 (279)	1.31 (294)	-22 to -1	Compacts easily
	2	1976.2 (5.29)	1.24 (279)			
	3	1999.0 (5.36)	1.44 (323)			
QPR-2000	1	1844.2 (4.94)	2.21 (497)	2.78 (626)	-12 to 10	Sticky; difficult to compact
	2	1835.1 (4.92)	3.16 (711)			
	3	1852.7 (4.96)	2.97 (668)			
Sylcrete-EV	1	2100.0 (5.63)	4.87 (1095)	5.83 (1311)	-1 to 21	Compacts easily
	2	1989.3 (5.33)	6.02 (1354)			
	3	2089.1 (5.60)	6.60 (1484)			
UPM (Spring & Fall Grade)	1	1907.4 (5.11)	3.41 (768)	3.46 (777)	-12 to 10	Compacts easily
	2	1954.2 (5.24)	3.41 (768)			
	3	1843.7 (4.94)	3.54 (796)			

¹ Workability temperature ranges from ASTM D 6704.
² Cold-mix paving material; not manufactured as a cold patch material, but tested for workability.

The specimens for the Marshall testing were not compacted using a Marshall compaction hammer but were instead compacted using the Corps of Engineers Gyratory Testing Machine (GTM). The GTM can compact to densities equivalent to those obtained with the Marshall hammer. The specimens were compacted to achieve a density equivalent to a 75-blow Marshall compaction. In order to be able to compact the mixtures for Marshall specimens, the specimens were cured and heated prior to compaction. The curing was required because these cold mixtures use either a cutback or an emulsified binder to provide workability at ambient temperatures. The method used was to place the mixture in a forced draft oven at 135 °C (275 °F) overnight (14 to 18 hr) and compact at that temperature. Specimens compacted under these conditions should represent the condition of the mixtures after being in place for several months. Table 7 provides the results of the Marshall testing conducted on the materials, including stability and flow values.

Table 7
GTM Compaction and Marshall Test Results

Material	Specimen No.	Specific Gravity ¹	Theor. Maximum Specific Gravity	Stability kN (lbf)	Flow 0.25-mm (0.01-in.)	Gyratory Stability Index (GSI)
Control	1			13.92 (3130)	13.0	1.0
	2			9.56 (2150)	12.5	1.0
	3			9.99 (2245)	12.5	1.0
	Average	2.308	2.528	11.16 (2508)	13	1.0
Cold Patch (Cold Weather)	1			5.07 (1140)	8.5	1.0
	2			5.43 (1220)	9.0	1.0
	3			5.12 (1150)	9.0	1.0
	Average	2.274	2.533	5.20 (1170)	9	1.0
DuraPave	1			8.83 (1985)	14.5	1.0
	2			13.28 (2985)	14.5	1.0
	3			13.32 (2995)	14.0	1.0
	Average	2.134	2.465	11.81 (2655)	14	1.0
ENVIROPATCH	1			3.25 (730)	7.0	1.0
	2			6.02 (1354)	6.5	1.0
	3			6.92 (1555)	7.5	1.0
	Average	2.347	2.679	5.50 (1213)	7	1.0
EZ Pave	1			7.30 (1640)	12.0	1.0
	2			8.38 (1885)	13.0	1.0
	3			7.98 (1795)	10.0	1.0
	Average	2.312	2.491	7.89 (1773)	12	1.0
EZ Street	1			9.67 (2175)	11.5	1.0
	2			9.45 (2125)	10.5	1.0
	3			11.45 (2575)	11.0	1.0
	Average	2.040	2.393	10.20 (2292)	11	1.0
Instant Road Repair	1			5.94 (1335)	15	1.0
	2			6.46 (1452)	13	1.0
	3			6.61 (1485)	12	1.0
	Average	2.201	2.461	6.33 (1424)	13	1.0
Optimix	1			7.94 (1785)	12.0	1.0
	2			6.52 (1465)	12.0	1.0
	3			8.19 (1841)	12.5	1.0
	Average	2.245	2.500	7.55 (1697)	12	1.0
Perma-Patch	1			4.58 (1030)	9.0	1.0
	2			5.34 (1200)	9.0	1.0
	3			5.12 (1150)	8.5	1.0
	Average	2.278	2.693	5.01 (1127)	9	1.0
QPR-2000	1			5.58 (1255)	11.0	1.0
	2			6.04 (1385)	7.0	1.0
	3			5.85 (1315)	11.5	1.0
	Average	2.229	2.549	5.86 (1318)	10	1.0
Sylcrete-EV	1			4.92 (1105)	13.0	1.0
	2			5.93 (1332)	12.5	1.0
	3			6.15 (1382)	12.5	1.0
	Average	2.253	2.545	5.66 (1273)	13	1.0
UPM	1			7.92 (1780)	10.0	1.0
	2			4.40 (990)	9.5	1.0
	3			6.14 (1380)	10.0	1.0
	Average	2.139	2.600	6.15 (1383)	10	1.0

¹ Results shown are from the evaluation of one specimen, except where other results are given.

Triaxial Compression Testing

One of the most common failures in asphalt pavements is caused by permanent deformation (rutting) under high traffic volumes and extreme loading conditions. To better understand the mechanism of the load carrying process through which asphalt mixtures undergo gradual permanent deformation that leads to failure, the fundamental response parameters of the material need to be obtained. One method to obtain these fundamental parameters is to conduct triaxial compression testing. Triaxial compression tests have also been used to evaluate the workability of cold patch mixtures. One study found that the angle of internal friction remained constant, but the cohesion value (y-intercept) increased with increased aging of the material (Estakhri and Button 1997).

In triaxial compression testing, an axial load is applied to a cylindrical specimen, along with a constant confining stress applied to all sides of the specimens. The axial stress-resistant properties of a material tested triaxially are derived from the relation between the testing load and the confining stress. Figure 3 shows a typical cold-mix specimen after triaxial testing. In the triaxial compression test method, the stress acting on an asphalt mixture specimen simulates the state of stress in flexible pavements while carrying traffic loading.

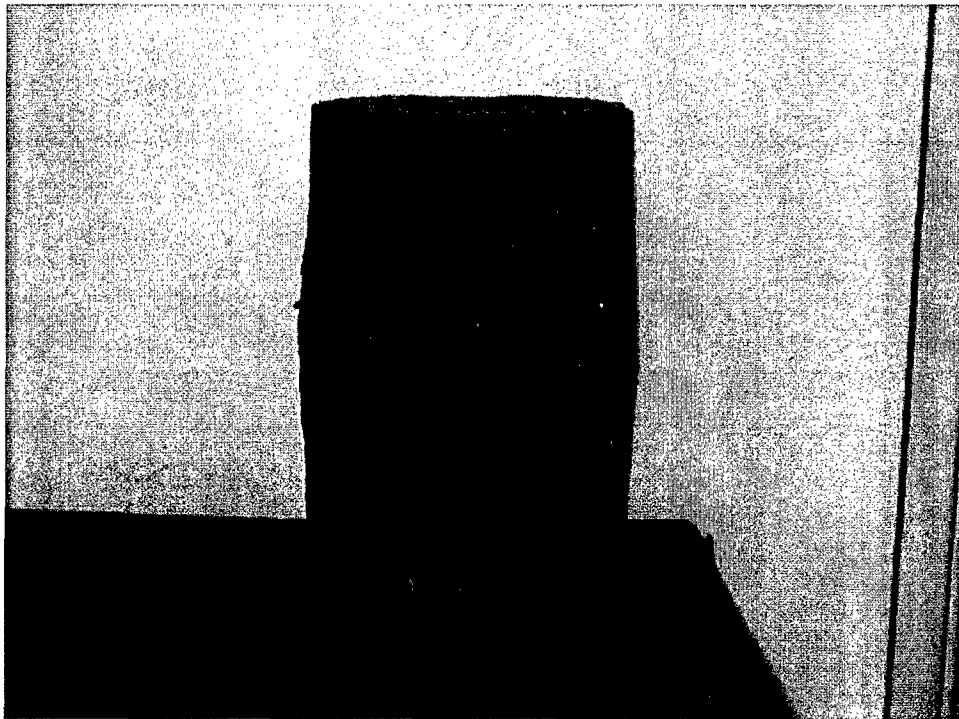


Figure 3. Typical specimen after triaxial testing

Equipment

The triaxial device used during testing was a full-feedback instrumented system. The following parameters are provided during testing: axial strain, horizontal strain, axial stress, and confining pressure. The confinement chamber is designed to accommodate Superpave gyratory compacted specimens (AASHTO 2002) up to 150 mm (6 in.) in diameter and 150 mm (6 in.) in height.

Testing protocol

Six cold patch materials were triaxially compression tested (Table 8). The test specimens were temperature conditioned for 24 hr at 10 °C (50 °F) before testing. This temperature was selected to provide test conditions that would reasonably represent the pavement temperature during trafficking of the repair test sections. Actual trafficking temperatures, as detailed in the following chapter, were somewhat in excess of this value. However, several repair materials could not be tested at temperatures exceeding 10 °C (50 °F). Four replicate 100- by 150-mm (4 - by 6-in.) specimens were produced for each cold patch material to be tested. Confining stresses of 0.0, 138.0, and 276.0 kPa (0, 20, and 40 psi) were used for the triaxial compression testing of the mixtures. A BISAR layered elastic analysis program was used to estimate the confining stresses developed in the pavement section, as detailed in Table 8. The approximate confining (horizontal) stresses of the asphalt layer were arbitrarily calculated at depths of 25 mm (1 in.), 63.5 mm (2.5 in.), and 100 mm (4 in.), as shown in Table 9. The total asphalt patches were placed to depths between 100 and 113 mm (4 to 4.5 in.). One test was conducted at the confining stresses of 0.0 kPa (0 psi) and 138.0 kPa (20 psi), and two tests were conducted at a confining stress of 276.0 kPa (40 psi). Field testing was the primary means used for evaluating the performance of the asphalt patching materials. A minimum number of triaxial compression tests were conducted to verify what was observed in the field.

Table 8
BISAR Input Parameters

Layer	Young's Modulus		Poisson's Ratio	Thickness	
	kPa	psi		mm	in.
Asphalt	1,380,000	200,000	0.40	100	4
Base	689,475	100,000	0.35	150	6
Subgrade	68,950	10,000	0.30	N/A	N/A

Table 9
BISAR Analysis Results

Asphalt Depth		Confining Stress	
mm	in	kPa	psi
25.4	1.00	276	40
63.5	2.50	138	20
100	4.00	0	0

The results of the triaxial compression tests for the cold patch asphalt specimens are provided in Tables 10a and 10b. The listed parameters include

confining stress, maximum compressive stress, and corresponding axial and horizontal (radial) strains. The specimens for the triaxial compression testing were not compacted using a Marshall compaction hammer but were instead compacted using the Superpave Gyratory Compactor (SGC) (AASHTO 2002). The SGC can compact to densities equivalent to those obtained with the Marshall hammer. The specimens were compacted to achieve a density equivalent to a 50-blow Marshall compaction.

The three confining pressures were used to define the stress envelope. A comparison was also made between the confined and unconfined compressive strength. This was done to analyze which materials show an increase in strength when confined. Some asphalt mixtures that exhibit low unconfined compressive strength and large volume changes may exhibit increased compressive strength and a reduction in volume change when confined.

Durability

The durability of a repaired area depends on the quality of both the mixture and the repair. This assumes that the amount of binder present in the mixture is correct and that the repair is properly placed and compacted. The durability of the repair mixtures was investigated through three parameters—compatibility, adhesion, and cohesion. One measure of mixture quality is the compatibility between binder and aggregate. If they are not compatible, the binder will not adhere to the aggregate (called stripping), and the repair will fail, usually through raveling. The compatibility between binder and aggregate is measured by mixing these materials together, exposing them to moisture, and then observing if there is a decrease in performance. This performance can be measured by either visual means, such as ASTM D 1664, or through comparisons of mechanical tests.

Cohesion is the property of a material being able to adhere to itself better than it adheres to materials around it. This means that a cold-mix material will not be displaced or removed from the patch by traffic but will remain cemented to the patch itself. The greater cohesiveness of a mixture the better it will perform, provided it is still sufficiently workable. The test method used for cohesion testing was developed from AASHTO TP-44-94 (AASHTO 1996), with the following exceptions. Place about 800 g of cold mix into a suitable pan and then place it into a refrigerator at $4 \pm 1^\circ\text{C}$ ($39 \pm 2^\circ\text{F}$). After the mix has been in the refrigerator for about 2 hr, remove it and immediately compact a Marshall specimen with five blows, each side. Then place the compacted specimen, still in the Marshall mold, back into the refrigerator for 4 to 6 hr. Leave the specimen in the mold until it is time to remove it for testing. The test procedure itself involves placing a compacted cold-mix specimen within a 305-mm (12-in.)-diam, 25.4-mm (1-in.)-opening metal sieve. A lid is placed on the sieve, and both the specimen and the sieve are stood on edge and rolled back and forth. The sieve is rolled back and forth 20 times, taking approximately 1 sec for each of the 20 passes. Tables 4a and 4b contain the results of cohesion testing on the various cold-mix materials.

Table 10
Repair Materials Evaluated by Triaxial Compression Test

Material	Type of Gradation	Confining Stress		Maximum Compressive Stress		Axial Strain mm/mm	Radial Strain mm/mm
		KPa	psi	KPa	psi		
DuraPave	Dense	0	0	1940	281	2.71×10^{-2}	1.90×10^{-2}
		138	20	2000	290	1.68×10^{-2}	6.01×10^{-3}
		276	40	1890	274	1.07×10^{-2}	2.07×10^{-3}
		276	40	1950	283	1.20×10^{-2}	3.40×10^{-3}
EZ Pave	Dense	0	0	2000	290	5.29×10^{-3}	1.47×10^{-3}
		138	20	1950	283	4.49×10^{-3}	4.38×10^{-4}
		276	40	1890	274	3.25×10^{-3}	2.18×10^{-4}
		276	40	1960	284	3.88×10^{-3}	5.93×10^{-4}
Instant Road Repair	Dense	0 (Damaged)	0 (Damaged)	N/A	N/A	N/A	N/A
		138	20	1400	203	2.03×10^{-2}	1.70×10^{-2}
		276	40	1920	278	1.59×10^{-2}	1.24×10^{-2}
		276	40	1800	261	1.77×10^{-2}	1.12×10^{-2}
Perma-Patch	Open	0	0	340	49	1.04×10^{-2}	8.66×10^{-3}
		138	20	1320	191	3.60×10^{-2}	2.37×10^{-2}
		276	40	1900	276	3.27×10^{-2}	1.93×10^{-2}
		276 (Damaged)	40 (Damaged)	N/A	N/A	N/A	N/A
QPR-2000	Open	0	0	200	29	1.15×10^{-2}	1.26×10^{-2}
		138	20	1120	162	2.84×10^{-2}	1.96×10^{-2}
		276	40	1740	252	2.68×10^{-2}	1.39×10^{-2}
		276 (Damaged)	40 (Damaged)	N/A	N/A	N/A	N/A
UPM	Open	0	0	260	38	1.93×10^{-2}	2.44×10^{-2}
		138	20	1260	183	2.60×10^{-2}	1.73×10^{-2}
		276	40	1860	270	6.55×10^{-2}	1.03×10^{-2}
		276	40	1850	268	3.14×10^{-2}	1.76×10^{-2}

Adhesion is the property of a material to adhere onto the surface upon which it is placed. This means that the material stays in the hole and adheres to the edge of the hole in which it was placed. The edges of the repairs are usually the weakest areas of the repair, in regard to opening and allowing water to penetrate into the substrata. The adhesion test used was similar to that detailed by Prowell and Franklin (1996) with several changes. The following details the test procedure used to determine adhesion. The cold mix for each test specimen was oven-aged by placing about 750 g (1.65 lb) in a forced-draft oven at 60 °C (140 °F) for 4 hr. This oven-aged cold mix was then cooled to room temperature prior to compaction. The Marshall cores, whose construction was previously described in the section *Strength*, were used for the adhesion test prior to Marshall testing. One face of each of the GTM-compacted cores used for the adhesion test was thin-cut with a concrete saw to expose an aggregate face on which the oven-aged mixture was compacted (Figure 4). The surface was cleaned and completely dried, and then slightly heated to help to get it back within the 150-mm (6-in.)-high GTM mold, with the cut face on the upper side. The oven-aged mix was placed on top of the Marshall core within the GTM mold and compacted with 10 blows of the Marshall hammer (Figure 5). After compaction, the oven-aged mix and the underlying Marshall core were extruded and then turned upside down and observed to determine the time it took for the oven-aged mix to come loose from the Marshall core. The time until separation was recorded up until 2 min. While recording the time until failure, it was also noted whether it was an adhesion or cohesion failure.

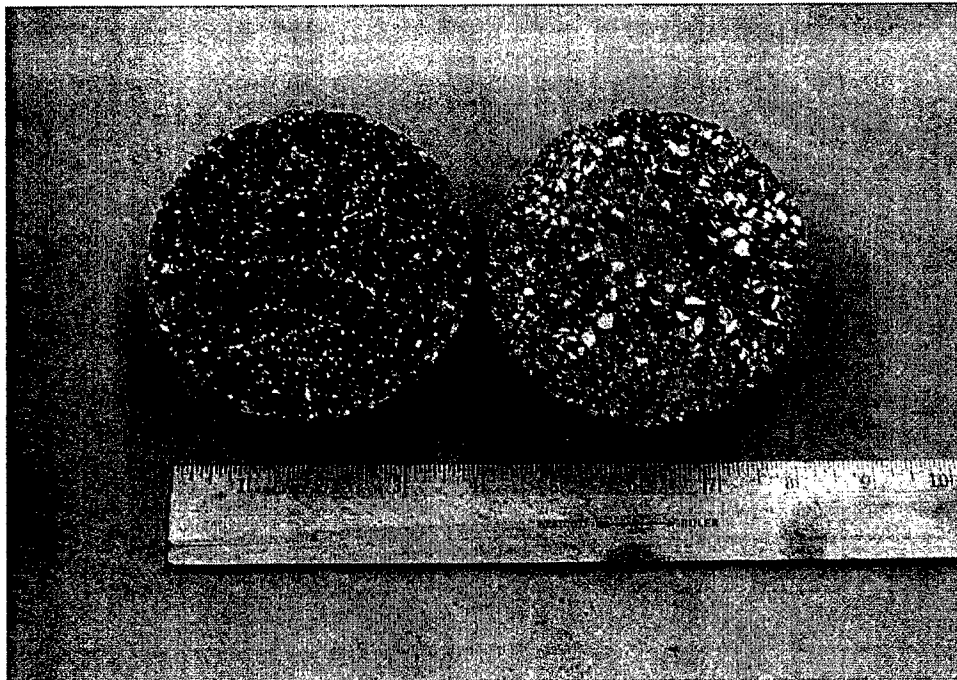


Figure 4. Compacted GTM core on left and similar core with cut face on right

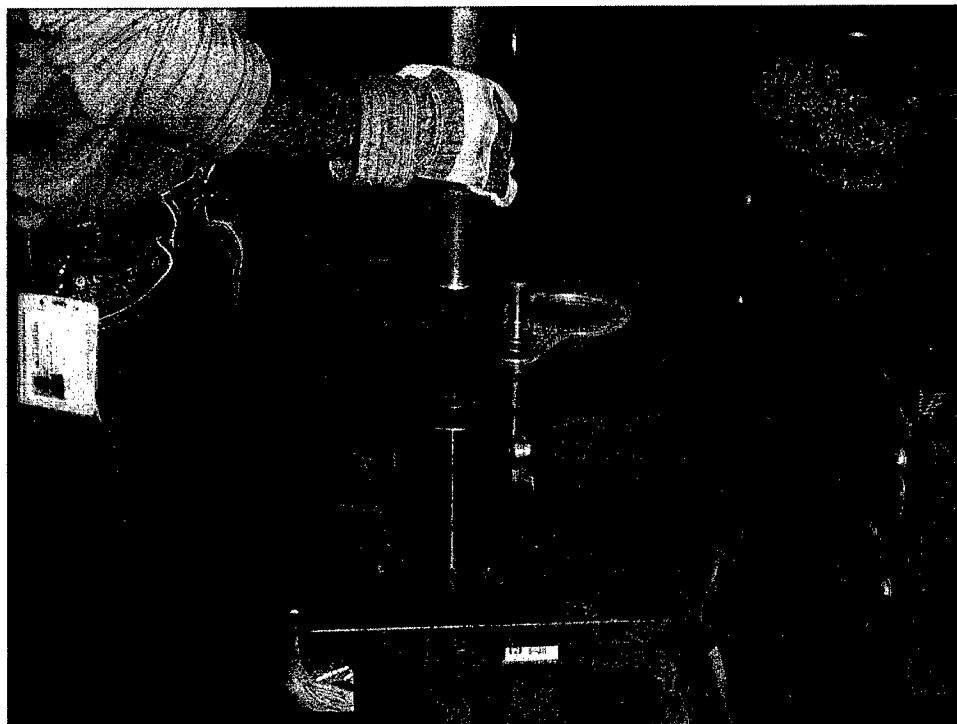


Figure 5. Marshall hammer used to compact cold mix onto asphalt core in GTM mold

If the vast majority of the oven-aged mix pulled free from the core, it was considered an adhesion failure. However, if some of the oven-aged mix remained on the

core, it was considered to be a cohesive failure (Figure 6). Tables 4a and 4b present the results of adhesion testing on the various cold-mix materials.

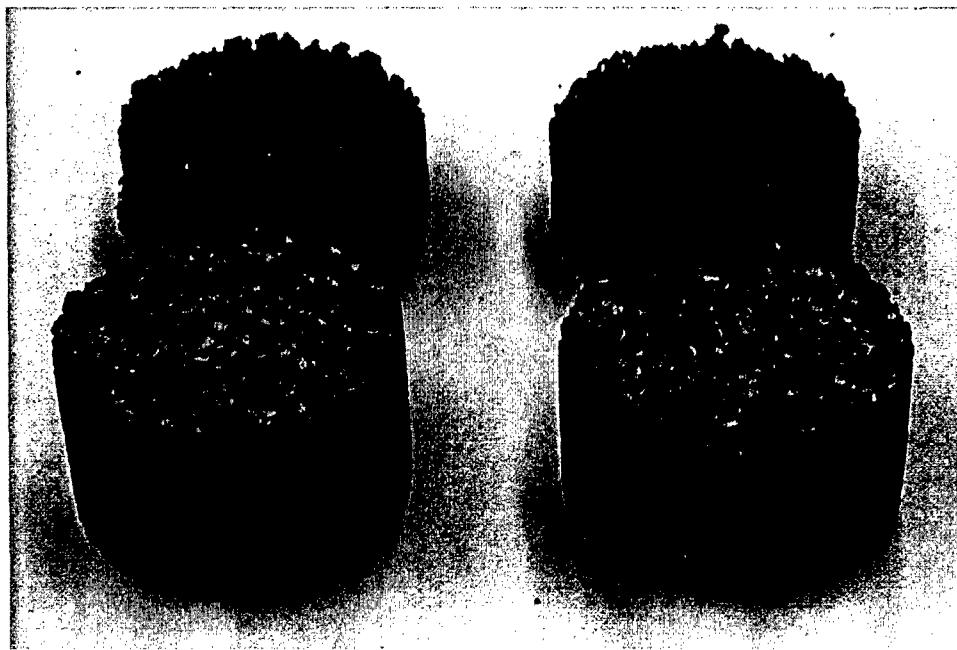


Figure 6. Both mixtures would be adhesion failures, although the core on the right does exhibit a partial cohesive failure

Results

The results of the workability tests indicate that open-graded mixtures generally have a higher workability (lower workability number) than dense- or well-graded mixtures. The workability values for cold-mix patch materials ranged from 1.31 N (294 lbf) to 6.45 N (1,450 lbf). Evaluation of the effect of the penetration or viscosity of the binders on workability was not possible in most cases due to various other mixture additives and other differences between the mixtures. The one exception was for the Cold Patch material, which did show some increased workability for the Cold versus the Hot Weather formulation.

The results of the Marshall tests (Table 7) indicate that, as expected, the mixtures with the denser or well-graded aggregates and with the harder binders (higher viscosities) tended to have the higher Marshall stability values. The stabilities varied between 5.01 kN (1,127 lbf) and 11.81 kN (2,655 lbf), with the majority falling below the standard high tire pressure requirement of 8.00 kN (1,800 lbf).

The results of the cohesion test conducted on the cold-mix materials showed that most materials were very cohesive. Except for the control mixture, all cold-mix materials showed some adhesive properties in the adhesion test. DuraPave, which had the lowest cohesive value, had the highest adhesive value. In fact, it

did not fail the adhesion test; the test was stopped at 2 min. Except for DuraPave, the overall results of most mixtures for the cohesion and adhesion tests were similar.

Overall, the maximum compressive stress of the open-graded mixtures is dependent on the confining stress, and the dense-graded mixture compressive stress is independent of the confining stress. The axial strain values for all mixtures were similar. The one exception was for the EZ Pave material, which did show lower axial strain values. The lower axial strain values may potentially indicate that the EZ Pave material will not easily densify when trafficked. The radial strain values for four of the mixtures were similar. The two exceptions were for the DuraPave and EZ Pave materials, which showed lower radial strain values. The lower radial strain value may potentially indicate that the DuraPave and EZ Pave materials will not easily shove or rut when trafficked.

5 Field Evaluation

The main objective of the field test section was to provide information concerning the placement and handling characteristics of several patch materials. A number of cementitious and cold-mix materials were selected to patch holes made in an asphalt pavement roadway. The selection of the tested materials was not based directly on expected performance but rather on the need to represent the range of materials that were laboratory evaluated. The selection of the asphalt materials was based on type of binder and on gradation of the aggregate within the mixtures.

Test Pavement

An HMA pavement section on the Engineer Research and Development Center-Vicksburg was selected as a site on which to place several repair materials. The site selected was part of a previously existing test road. The test items were placed in an area of the road that contained 100 mm (4 in.) of HMA over a 150-mm (6-in.) crushed stone base (Figure 7). The center section of this area of the road was selected as the location for placing the test items. The items were all placed in a line down the center of the roadway section (Figure 8). The individual test items were about 0.5 m (20 in.) wide and 0.9 m (36 in.) long. The holes for these items were cut with a dry-cut saw through the HMA and then pried out; the removed material was wasted.

Materials

Cementitious

Four rigid patch materials were placed in the test section: ABC Cement, alkali-activated slag concrete (AASC), PaveMend 15, and PaveMend 30.

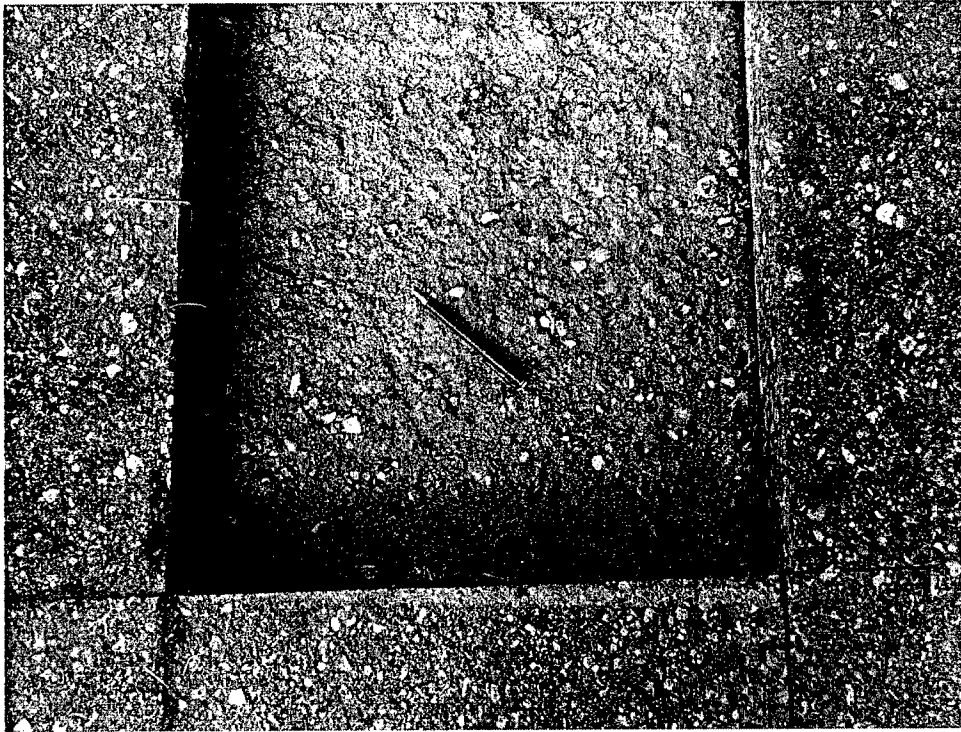


Figure 7. Close-up of base course material directly under HMA pavement



Figure 8. Overview of test area prior to removal and patching

Asphalt

Five cold patch materials were placed in the test section: DuraPave, Instant Road Repair, Optimix, QPR, and UPM. A control mixture consisting of an MC-800 binder and a well-graded blend of aggregates, as described in Tables 4a and 4b, was also placed (Figure 9). This control mixture was used to represent a typical cold mix and was designed to meet the requirements of UFGS 02742 (UFGS 1997). Information for the control mixture was also obtained from the Asphalt Institute's publication MS-16 (Asphalt Institute 1997) and the manual UFC 3-250-03 (UFC 2001).



Figure 9. Control mixture laid out to warm for ease of placement

Placement of Test Section

The placement of the materials occurred over a period of 2 days. The weather was hot, with high temperatures of about 35 °C (95 °F) and overnight lows of about 22 °C (72 °F). The days were generally sunny, and no precipitation fell during the placement. The Pavement 15 and the ABC Cement were placed on the first day; the Pavement 30 and the AASC were placed the second day. The components for the Pavement 15 were allowed to sit in the sun for a few hours prior to placement. These components were mixed using a high-speed vertical mortar mixer and then dumped directly into the hole (Figure 10). The hole was filled in two layers using two separate batches of the material. The Pavement 15 set very quickly, and only a quick troweling of the surface was possible before it

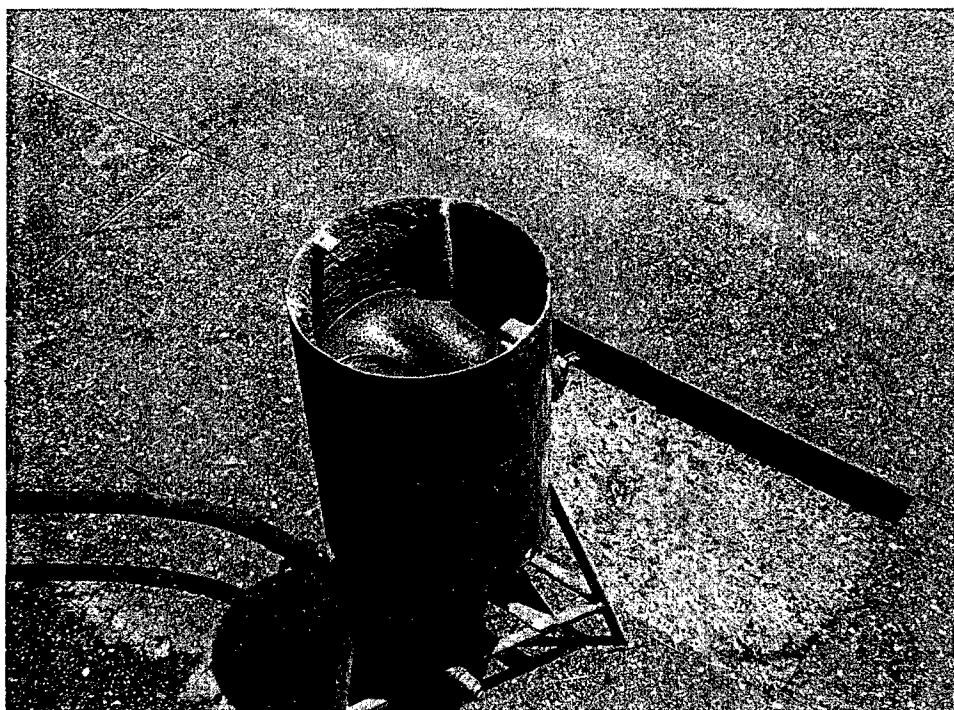


Figure 10. Air-driven paddle mixer, used with PaveMend 15

hardened. PaveMend is self-leveling, and finishing may not be necessary. The ABC Cement was mixed in a portable drum-vane mixer (Figure 11). After mixing, the material was dumped directly into a hole and screeded with a board. The mixture was consolidated using a small electric vibrator and then floated and finished (Figure 12). The next day, the components for the PaveMend 30 were kept at room temperature until right before mixing. The components were mixed directly in the bucket that the material was shipped in, as given in the manufacturer's instructions, using a blade mixer and an electric drill. After mixing, the material was dumped into a hole, and other buckets were mixed and added until the hole was full. Both PaveMend products are self-leveling and therefore will form a level surface, which should be considered when there is a slope on the pavement surface. The fourth and last product, placed on the second day, was an AASC. This concrete mixture was developed and patented by the Corps of Engineers for rapid pavement repair. It was mixed in the portable drum-vane mixer, dumped into the hole, screeded with a board, vibrated, floated, and finished (Figure 13).

The proprietary cold-mix products were placed over the same 2-day time period as the asphalt materials. The cold-mix materials were placed in the holes in two lifts (Figure 14). The first lift was compacted initially with several coverages of a tamping compactor with a 125-mm (5-in.)-diam circular head (Figure 15). The remaining compaction of the first lift was accomplished with about 12 to 15 passes with a vibratory plate compactor. The second lift was compacted in the same manner except only the plate compactor was used (Figure 16). With the exception of the control mixture that was placed in only a dry hole, each of the other mixtures was placed in both dry and wetted holes. To wet the holes, enough

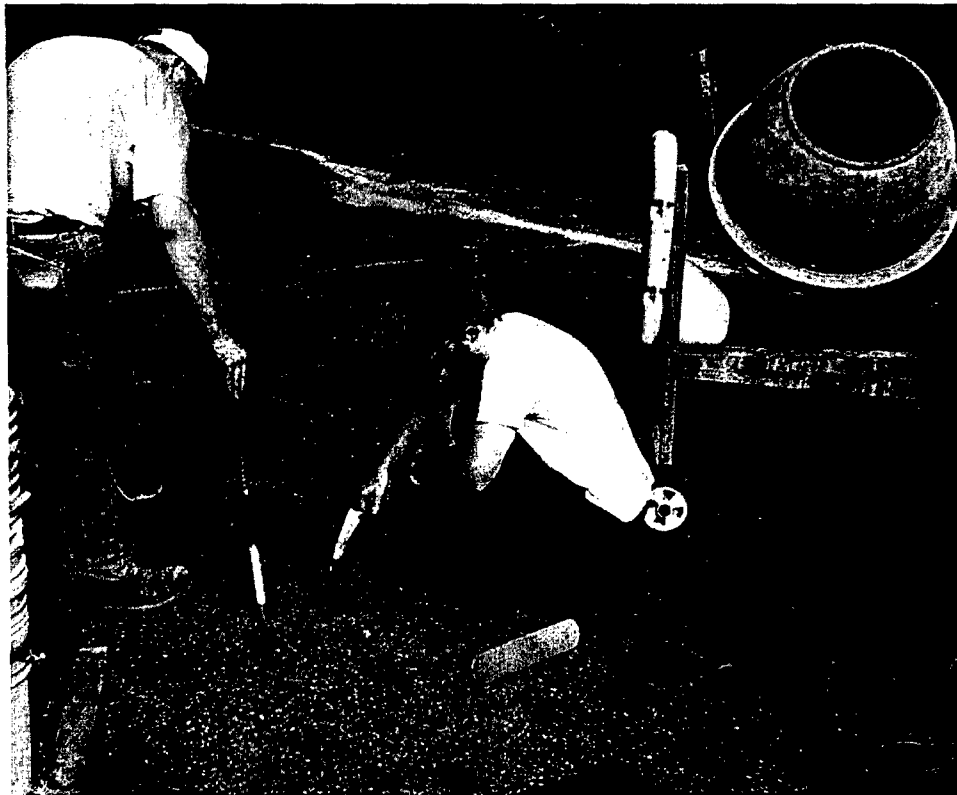


Figure 11. Vibrating the ABC Cement. Shown on the right is the rotary vane mixer used for mixing



Figure 12. Finishing a patch with a trowel



Figure 13. Finished rigid repairs prior to trafficking. From the foreground to the background, the patches were Pavemend 30, AASC, Pavemend 15, and ABC Cement



Figure 14. Placing cold patch directly into the hole from the bucket



Figure 15. Using tamping compactor to compact cold mix



Figure 16. Using a vibratory plate compactor

water was added to saturate the hole and leave somewhere between 12.5 and 25 mm (0.5 to 1 in.) of water in the hole prior to the introduction of the cold-mix material (Figure 17). Materials that the manufacturers said could be placed in wetted holes and/or displace free water worked very well in the wetted holes (Figure 18). The dry-hole patches were placed on the first day, and the wet-hole patches were placed on the second day. The control cold mix was spread out and allowed to warm in the sunshine prior to placement. This allowed for the larger chunks of the patch material to be broken up, during placement.

Traffic

The vehicle used to traffic the repaired areas was an Oshkosh, PQT (Figure 19). This dual-axle truck was loaded with 5 tons of payload, and the super-single tires were 14.00R20 XZL Michelin tires. The specifications on the truck and its tires are given in Table 11. The performance of the patches under traffic is summarized in Table 12. The holes patched on the first day were given four passes with traffic on the same day. The holes placed the second day and those placed the previous day were given six passes. The following day (the third day) all patched holes, both asphalt and cementitious, were eventually given a total of 70 passes with all three tires on the driver's side of the truck. The last 10 passes were applied after the asphalt patch material in holes 2, 3, 5, 8, 9, and 10 had been reworked or leveled. The mixture in these holes had to be reworked because, after trafficking, the material upheaved above the level of the surrounding pavement. The passes were applied as much as possible down the middle of the patched areas.

Table 11
Information on Truck Used for Trafficking

	Front Axle	Middle Axle	Rear Axle
Vehicle type	Oshkosh, PQT (Flatbed Truck)		
Mass per axle, ¹ kg (lb)	4,773 (12,789)	4,914 (13,165)	4,902 (13,133)
Tire characteristic			
Tire ID	14.00R20 XZL, Michelin		
Tire width, mm (in.)	336 (13.2)		
Tire pressure, ² kPa (psi)	283 (41)	393 (57)	393 (57)
Contact area, ² sq cm (sq in.)	2394 (371)	2316 (359)	2303 (357)
¹ Vehicle had 5 tons of ballast on the truck bed.			
² Values determined with 425/95 R20 XZL Michelin tire.			



Figure 17. Adding cold-mix patch material to a hole filled with water



Figure 18. Water displaced from hole during compaction



Figure 19. Trafficking on cold-mix repaired areas

Table 12
Effect of Traffic on Patching Materials

Location No.	Material	Wetted	Depth Change with Number of Passes, mm (in.)		
			Initial	Final ¹	Effective Final ^{1,2}
1	DuraPave	Y	4 (1/4)	---	---
2	QPR	Y	2.5 (3/32)	9.5 (3/8)	4 (5/32)
3	UPM	Y	3 (1/8)	12.5 (1/2)	6 (1/4)
4	Instant Road Repair	Y	6 (1/4)	12.5 (1/2)	3 (1/8)
5	Optimix	Y	3 (1/8)	9.5 (3/8)	3 (1/8)
6	Instant Road Repair	N	8 (5/16)	16 (5/8)	5 (3/16)
7	Control	N	9.5 (3/8)	17.5 (11/16)	5 (3/16)
8	Optimix	N	-1.5 (-1/16) ⁴	9.5 (3/8)	11 (7/16)
9	QPR	N	-1.5 (-1/16) ⁴	9.5 (3/8)	11 (7/16)
10	UPM	N	-1.5 (-1/16) ⁴	9.5 (3/8)	11 (7/16)
11	DuraPave	N	8 (5/16)	19 (3/4)	8 (5/16)
12	PaveMend 15	N	---	---	---
13	ABC Cement	N	---	---	---
14	PaveMend 30	N	---	---	---
15	AASC	N	---	---	---

¹ After 60 passes, longitudinal measurement at center of repair.

² Effective final height includes reduction for 3 mm (1/8 in.) rutting of surrounding HMA pavement.

³ Placed in water, against manufacturer's recommendations, left to dry for 2 days, the patch could be trafficked with only minor movement.

⁴ Negative number indicates the elevation was above the level of the pavement.

⁵ Repair showed no distress from traffic; however, there was some rutting of HMA between patches, and patch rocked or moved under traffic.

Performance

The overall performance of the rigid repairs was very good. The rigid patches showed no distress after traffic (Figure 20). Because of their relatively high stiffness or modulus value compared with the surrounding asphalt pavement, the rigid patches started rocking and moving under traffic in relation to the surrounding asphalt pavement. The severity of this type of problem would probably increase with increasing temperatures and decrease with decreasing temperatures, because of changes in the surrounding HMA and the underlying base course. The HMA experienced some rutting between the rigid patches, which was probably a major contributor to the rocking of the rigid patches.

The overall performance of each of the asphalt materials placed in the test section was similar. Each material experienced some additional compaction under traffic, as evidenced by the slight rutting that occurred. Of note is the fact that the surrounding asphalt pavement also rutted under the traffic applied. This rut depth was about 3 mm (1/8 in.) throughout the trafficked area. The depth of ruts as given in Table 12 varied from 3 to 11 mm (1/8 to 7/16 in.). In all cases, the depth of the rut was somewhat larger when the patch material was not restrained within the patch. In other words, the amount of rutting was greater when the hole was overfilled. All the materials exhibited a degree of cohesion, especially the mixtures in holes 2, 3, 5, 8, 9, and 10, as these mixtures were reworked and then trafficked without first being recompacted, and there was no noticeable pickup by the tires. Except for the control mixture, after compaction and numerous passes of traffic, any of the patch materials could easily be scarified, leveled, and recompacted without pickup on the wheels.

The five proprietary products were all relatively easy to handle, place, and compact. The manufacturer of DuraPave stated that the product could be placed in a wet hole but did not recommend it for displacing water. The excess water acted to prevent compaction and resulted in an unstable mixture that stabilized on its own after drying for a few days and was then able to withstand traffic. The control mixture was somewhat stiffer than the other products; however, using solar heating by spreading it out in the sun for about 1/2 hr made it sufficiently easy to place and compact. Because it was a conventional cutback cold mix, the control mixture was placed only as a dry patch. Table 13 gives a subjective estimate of the workability and rate of curing of the mixtures under field conditions.

Table 13
Estimation of Field Workability of Cold Mixtures

Location No.	Material	Workability At Given Time After Placement ¹			
		Initial	3 Weeks, Warm ²	6 Weeks	
				Warm ²	Cool ²
1	DuraPave	5	3.5	2	1
2	QPR	5	5	3.5	0
3	UPM	5	5	3.5	0
4	Instant Road Repair	5	1	0.5	0
5	Optimix	5	4	2	0
6	Instant Road Repair	5	1.5	0.5	0
7	Control	4	0	0	0
8	Optimix	5	4	2	0
9	QPR	5	5	3.5	0
10	UPM	5	5	3.5	0
11	DuraPave	5	3.5	2	0.5

¹ Field workability was based on subjective evaluation of ability of mixture to be worked or penetrated with a sharp spade. Scale based from 0 to 5, with 0 being difficult to mark and 5 being relatively easy to penetrate and move.

² Warm refers to a sunny day with temperatures of about 32 °C (90 °F), while cool refers to a cloudy day with temperatures of about 24 °C (75 °F).

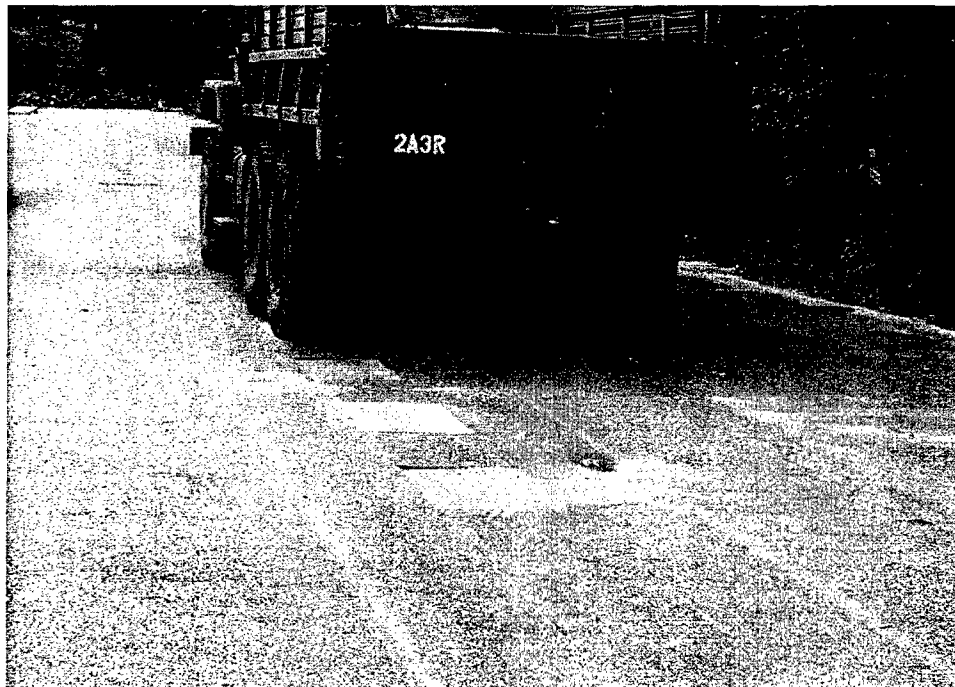


Figure 20. Trafficking on rigid repair areas

6 Conclusions

The following conclusions can be drawn from this investigation of repair products for expedient roadway pavements. A large number of proprietary repair products are available for both concrete and asphalt pavements, and only a few of these products were investigated. Products that were not part of this investigation or even listed in the appendixes may perform as well or better than those selected for this study. No long-term field performance conclusions can be drawn from this study.

Rigid Repair Materials

Trafficking on the areas repaired with the rigid materials had no effect on the repair materials themselves; however, after several passes, the HMA between the patched areas started to rut and, eventually, the repairs started to move or rock under the wheels of the vehicle. This type of failure of rigid repair materials used in flexible pavement surfaces is typical due to the movement of the flexible material in relation to the rigid pavement.

Asphalt Repair Materials

The asphalt cold-mix repair products that were investigated in the laboratory and in the field all performed well. The workability test values of these products showed that they would all be considered workable down to the freezing point of water and slightly below. Aggregate gradation probably has a greater effect on workability than the grade of the binder. The Marshall stability test is probably not a good indicator of performance because it is not an appropriate test for open-graded mixtures. The materials tested showed good cohesive and adhesive properties. The control mixture did not show adhesive properties, indicating that a tack coat would be required to achieve adhesion in the repaired area.

The cold-mix materials were all easier to apply in field repair test sections when compared with the control mixture. The repair materials were able to carry the applied load without excessive displacement. When material was displaced, it could easily be releveled and trafficking continued without any loss of material. The four cold-mix products that advertised application to a wet pavement

performed very well and did not show any difference in performance between the dry and watered holes.

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Appendix A

Fact Sheets – Repair Materials Evaluated

<u>Repair Material</u>	<u>Page</u>
Cold Patch (Winter/Summer Grades)	A2
DuraPave	A4
ENVIROPATCH	A5
EZ Pave	A7
EZ Street	A9
Instant Road Repair	A11
Optimix	A13
Perma-Patch	A15
QPR (Quality Pavement Repair)	A16
Sylcrete EV (Extra Value Cold Mix)	A18
UPM (Unique Paving Materials)	A20
ABC Cement	A22
USACE Alkali-Activated Slag Concrete (AASC)	A23
PaveMend™	A25

1. Name: Cold Patch (Winter/Summer Grades)

2. Manufacturer:

Matrex Company
3290 Greenburn Place
Locust Hill, Ontario, Canada
Telephone: (905) 619-2525
Fax: (905) 619-9781
www.matrexstar.com

3. Description:

Matrex Cold Patch is an aggregate-specific cold-mix patch material for asphalt and concrete pavements. The binder is a proprietary blend of cutback asphalt cement, high-grade co-polymers, and diluents. The open-graded mixture has been made with limestone, sandstone, or granite aggregates.

4. Manufacturer's Provided Information:

Information on the patch material is provided in the table below.

Sieve Size	Aggregate Gradation (Percent Passing)	
12.5 mm (1/2-in.)	100	--
9.5 mm (3/8-in.)	90-100	100
6.7 mm (1/4-in.)	---	95-100
No. 4	20-55	55-100
No. 8	---	0-30
No. 16	0-10	0-5
No. 50	0-5	---
No. 200	0-2	0-2
Binder	Winter Grade	Summer Grade
Binder Content (%)	4.0 to 7.0	
Viscosity (ASTM D 2170)	300-500 cSt @ 60 °C (140 °F)	800-4000 cSt @ 60 °C (140 °F)
Residue by Distillation, @ 360 °C (680 °F) Percent Original Volume (D 402)	72-78	78-92
190 °C (374 °F)	0.0	0.0
225 °C (437 °F)	0.0	0.0
260 °C (500 °F)	0-5	0-5
316 °C (600 °F)	0-25	0-25
Residue		
Penetration (ASTM D 5 – D 217)	200 Minimum	200 Minimum
Ductility (ASTM D 113)	100 Minimum @ 21 °C (70 °F)	100 Minimum @ 21 °C (70 °F)
Solubility (ASTM D 2042)	97.5%	97.5%
Air Temp. Application Range	-26 °C (-15 °F) to Undefined	Above Freezing
Approximate Compacted Yield	50 to 65 kg/m ² per 2.5 cm (100 to 120 lb/yd ² per 1 in.)	

Mixture Preparation:

The Cold Patch binder can be mixed with local aggregates heated to a temperature range of 25 °C (77 °F) to 120 °C (248 °F). The combined mixture can be stockpiled and effectively maintained in uncovered stockpiles of 100 tons or more.

Application Conditions:

The area to be patched can be wet, but it should be free of loose debris and standing water. A prime or tack coat is not required. The cold patch should be placed in layers about 25 mm (1 in.) thick, with compaction not required but recommended, especially in areas with heavier loads or high tire pressures. No curing time is required; open to traffic immediately.

5. Physiographic Factors:

Cold Patch can be obtained in 27.2-kg (60-lb) buckets, or the binder material can be purchased for use with suitable aggregates. Containers of the patch material may be stored outdoors in extreme temperatures but should be covered for long-term storage. The shelf life in sealed containers is 2 years, with longer periods possible when they are stored at moderate levels of temperature and humidity. To better facilitate placement, the patching material should be allowed to warm as high above freezing as possible, without directly heating the material (i.e., to normal room temperature). The shelf life of the binder material is about 1 year when stored in proper containers at moderate levels of temperature and humidity. The shelf life of the Cold Patch mixture, when stored outside in an uncovered area can be as much as 2 years.

The cost of a 27.2-kg (60-lb) pail of Cold Patch will vary with the location. The binder material can be purchased for use with suitable local aggregates.

6. Discussion and Recommendations:

Cold Patch is widely used throughout the United States and North America. The material is manufactured in Canada, and the binder's properties (winter or summer mixture) are adjusted to allow for this product to be used within any geographical region. Cold Patch is marketed as a permanent pothole repair material for any asphalt pavement.

1. Name: DuraPave

2. Manufacturer:

DuraPave, Inc.
Post Office Box 84
Carrboro, NC 27510-0084
Telephone: (919) 967-0887
Fax: (919) 933-8584

3. Description:

DuraPave is a cold-mix patch material for asphalt pavements. The binder is a proprietary blend of recycled asphalt and other petroleum ingredients in a water emulsion. The aggregate is a well-graded blend of aggregates

4. Manufacturer's Provided Information:

Application Conditions:

The area to be patched can be wet, but it should be free of loose debris and standing water. A prime or tack coat should not be used. The minimum depth of patch should be about 12.5 mm (1/2 in.), with a maximum compacted layer thickness of 75 mm (3 in.). Thicker layers should be placed in approximately 50-mm (2-in.) thick lifts. No curing time required—mound material and compact with traffic or compact with standard asphalt compaction equipment.

5. Physiographic Factors:

The standard packaging of the patch material is in 27.2-kg (60-lb) pails. Containers of the patch material may be stored outdoors in extreme temperatures, but should be covered for long-term storage. To better facilitate placement, the patching material should be allowed to warm as high above freezing as possible, without directly heating the material (i.e., to normal room temperature). The shelf life in sealed containers is 1-year, with longer periods possible when they are stored at moderate levels of temperature and humidity. The cost of a 27.2-kg (60-lb) pail of DuraPave is \$33.60 FOB Carrboro, NC.

6. Discussion and Recommendations:

DuraPave is widely used throughout the state of North Carolina and in several other states. The material is manufactured for one geographical location (North Carolina), and the binder properties are not varied for seasonal changes. The material is marketed as a permanent pothole repair material for any asphalt and concrete pavement surface.

1. Name: ENVIROPATCH

2. Manufacturer:

Vulcan Materials Co.
Midsouth Division
Shallowford Road
Chattanooga, TN 37411
ATTN: Ralph Maddox
Telephone: (423) 892-3677
Fax: (423) 892-5979

3. Description:

ENVIROPATCH is a cold-mix patch material for asphalt pavements. The binder is a proprietary inverted asphalt emulsion. The aggregate can be either an open- or dense-graded. The manufacturer has used crushed limestone and some granite as the aggregate.

4. Manufacturer's Provided Information:

Information on the patch material is provided in the table below.

Sieve Size	Aggregate Gradation (Percent Passing)	
	Open Graded	Dense Graded
1/2-in.	100	100
3/8-in.	90-100	90-100
No. 4	20-55	55-85
No. 8	5-30	32-67
No. 16	0-10	18-48
No. 30	0-7	10-33
No. 50	0-5	5-15
No. 100	---	---
No. 200	0-2.5	2-6
Binder Content (%)	4-7	
Penetration (ASTM D 5)	200 Minimum	
Stripping (ASTM D 1664)	95% Minimum Coated	
Air Temp. Application Range	4 °C (40 °F) to 75 °C (168 °F)	
Approximate Compacted Yield	62.7 kg/m ² per 2.5 cm (115 lb/yd ² per 1 in.)	

Mixture Preparation:

The ENVIROPATCH binder and aggregates should be heated to a maximum temperature of between 77 °C (170 °F) to 88 °C (190 °F) for mixing. The combined mixture should be stockpiled in up to 2-m (6-ft) depths until it has reached ambient temperature, and then it can be effectively maintained in uncovered stockpiles of 100 tons or more.

Application Conditions:

The area to be patched can be wet, but it should be free of loose debris and standing water. A prime or tack coat should not be used. The minimum depth of patch should be about 25 mm (1 in.), with a maximum compacted layer thickness of 75 mm (3 in.). Thicker layers should be placed in approximately 50-mm (2-in.) thick lifts. No curing time required—mound material and compact with traffic. In areas with heavier loads or high tire pressures, (i.e., airfield pavements), compact with a vibratory plate compactor or other compaction equipment.

5. Physiographic Factors:

ENVIROPATCH can be purchased for use with suitable aggregates. Containers of the binder material can be stored outdoors; however, long-term exposure to below-freezing temperatures will adversely affect the performance of the binder, causing it to become ineffective. The shelf life of the binder material is about 3 months, with longer periods possible when they are stored at moderate levels of temperature and humidity. To better facilitate placement, the patching material should be allowed to warm as high above freezing as possible, without directly heating the material (i.e., to normal room temperature or above). The binder material can be purchased for \$1.26/gallon FOB Chattanooga, TN, for use with suitable local aggregates.

6. Discussion and Recommendations:

ENVIROPATCH is widely used throughout several southeastern states, including Tennessee, Kentucky, Georgia, and Alabama. The properties of the ENVIROPATCH binder are designed to meet the requirements of the known climatic conditions and the characteristics of the local aggregate. ENVIROPATCH is marketed as a pothole repair material for any asphalt pavement. Although ENVIROPATCH does qualify as a high-performance patch material in Tennessee and Kentucky, the company does not claim to provide a permanent repair.

1. Name: EZ Pave**2. Manufacturer:**

Matrex Company
3290 Greenburn Place
Locust Hill, Ontario, Canada
Telephone: (905) 619-2525
Fax: (905) 619-9781
www.matrexstar.com

3. Description:

EZ Pave is an emulsified cold-mix, cold-laid paving mixture for pavement overlays. The binder is an emulsified proprietary blend of asphalt cement, emulsifying agents, and water. A wide variety of gradations can be used, either open- or dense-graded, and can include almost any type of acceptable aggregates including limestone, sandstone, or granite.

4. Manufacturer's Provided Information:

Information on the patch material is provided in the table below.

Sieve Size	Typical Aggregate Gradations (Percent Passing)			
19.0 mm (3/4-in.)	100			100
12.5 mm (1/2-in.)	84.9	100	100	81.4
9.5 (3/8-in.)	52.0	74.7	91.3	58.0
4.75 mm (No. 4)	6.5	3.1	6.8	39.9
2.36 mm (No. 8)	0.4	1.1	1.4	31.6
1.18 mm (No. 16)	0.3	---	---	26.6
600 μm (No. 30)	---	---	---	22.5
300 μm (No. 50)	---	---	---	15.9
150 μm (No. 100)	---	---	---	8.1
75 μm (No. 200)	0.1	1.0	---	3.1
Binder				
Binder Content (%)	4.5 to 6.0, Typically			
Viscosity (ASTM D 88)	60 SFs @ 50 °C (122 °F), Typical			
Residue by Distillation, @ 260 °C (500 °F), Percent Original Volume (D 244)	66.0, Typical			
Residue				
Penetration (ASTM D 5)	200, Typical			
Solubility (ASTM D 2042)	97.5%, Typical			
Air Temp. Application Range	Above 15 °C (60 °F)			
Approximate Compacted Yield for 9.5-mm (3/8-in.) Aggregate	60 to 65 kg/m ² per 2.5 cm (110 to 120 lb/yd ² per 1 in.)			

Mixture Preparation:

The EZ PAVE binder can be mixed with local aggregates heated to a temperature range of 25 °C (77 °F) to 82 °C (180 °F). Prior to mixing, the manufacturer's mix design analysis will determine the quantity of surface-active ingredients and/or antistripping agent needs.

Application Conditions:

The area to be paved should be a clean and dry pavement surface, and free of deleterious materials. A tack coat is not required, but can be used if available. The EZ Pave should be applied with a compacted layer thickness of about 25 mm (1 in.). Thicker applications should be constructed with these 25-mm (1-in.) lifts. The mixture should be compacted with conventional steel-wheel and pneumatic rollers. Care must be taken not to overcompact the mixture and break down the aggregate. When formulated to carry traffic within a short time of placement, the resulting shelf life of the stockpile will be shorter. The compacted surface can be dusted with fine sand or portland cement to allow for traffic within a shorter period of time.

5. Physiographic Factors:

EZ Pave can be obtained in bulk from the manufacturer. The binder can be adjusted for the intended application and for local aggregates. The EZ Pave mixture is not intended for long-term stockpiling but should normally be used shortly after mixing. The mixture can be bagged for short-term storage, but extreme temperatures, especially high temperatures, will rapidly reduce this time. The cost of the EZ Pave binder will vary with the project location, and an estimate should be obtained from the manufacturer.

6. Discussion and Recommendations:

EZ-Pave is widely used throughout the United States. The EZ Pave binder material is manufactured in Ontario, Canada, and the binder properties are adjusted for local conditions. EZ Pave is marketed as a cold-mix, cold-laid overlay material for any asphalt pavement.

1. Name: EZ Street**2. Manufacturer:**

The EZ Street Company
4649 Ponce de Leon Blvd.
Suite 400
Miami, FL 33018
Telephone: (800) 734-1476, (305) 663-3090
Fax: (305) 663-0832
E-mail: info@ezstreet-miami.com
www.ezstreet-miami.com

3. Description:

EZ Street is a cold-mix asphalt patch material for asphalt and concrete pavements. The binder is a proprietary blend of cutback asphalt cement, RAIP (Reactive Aggregate Insertion Polymer). The aggregate is a well-graded crushed limestone or other locally available aggregate.

4. Manufacturer's Provided Information:

Information on the patch material is provided in the table below.

Sieve Size	Aggregate Gradation (Percent Passing)	
1/2-in.	100	
3/8-in.	90-100	
No. 4	64-74	
No. 8	41-49	
No. 16	25-33	
No. 30	16-22	
No. 50	10-16	
No. 100	4-11	
No. 200	1.5-4.5	
Binder - Viscosity (ASTM D 2170)	350-4,000 cSt @ 60 °C (140 °F)	
Residue		
Penetration (ASTM D 5 – D 217)	180 Minimum	
Ductility (ASTM D 113)	100 Minimum	
Viscosity (ASTM D 2171)	75-425 poises @ 60 °C (140 °F)	
Residue by Distillation, @ 360 °C (680 °F) Percent Original Volume (D 402)	Total Distillate: 0-0	Original Volume: 73-95
225 °C (437 °F)	0-0	0-0
260 °C (500 °F)	0-0.5	0-5
316 °C (600 °F)	10-65	0-18
Mixture		
Stripping (ASTM D 2489)	95% Minimum	
Flash Point (ASTM C 92)	94 °C (200 °F)	
Binder Content (%)	Varies with aggregate type and gradation	
Application Air Temperature Range	-26 °C (-15 °F) to 38 °C (100 °F)	
Approximate Compacted Yield	60 kg/m ² per 2.5 cm (110 lb/yd ² per 1 in.)	

Application Conditions:

The area to be patched should be free of loose debris, but it can be wet and will displace some water. A prime or tack coat should not be used. The minimum depth of patch should be about 25 mm (1 in.), with a maximum compacted layer thickness of about 100 mm (2 in.). Thicker layers should be placed in approximately 50-mm (2-in.) thick lifts. No curing time is required—just overfill material and compact with compaction equipment or traffic. In areas with heavier loads or high tire pressures (i.e., airfield pavements), vibratory plate compactor or standard asphalt compaction equipment is recommended. After placement and compaction, EZ Street will cure in 7 days.

5. Physiographic Factors:

The standard packaging of the EZ Street patch material is in a 22.7-kg (50-lb) polyvinyl resealable zipper bag. EZ Street is also available in 909-kg (2,000-lb) Super Sacks. These containers allow the patch material to be stored outdoors in extreme temperatures, but should be covered for long-term storage. To better facilitate placement, the patching material should be allowed to warm as high above freezing as possible, without directly heating the material (i.e., to normal room temperature). The shelf life in sealed containers is 1 year, with longer periods possible when they are stored at moderate levels of temperature and humidity. The shelf life of a stockpile of 100 tons or more is at least 1 year.

The cost of a 22.7-kg (50-lb) bag or 909-kg (2,000-lb) Super Sack of EZ Street will depend upon local retail costing. The cost for the bag will vary from \$8 to \$10 and the cost for the sack will be about \$150. The cost of the EZ Street binder varies with the location of the project in relation to the blending terminal. The total cost of the patching material is dependent on the binder cost and that of suitable local aggregates. The average cost of the EZ Street mixture will be about \$65/ton FOB from the producer's stockpile.

6. Discussion and Recommendations:

EZ Street is used by state highway departments throughout the United States. The material is manufactured in Florida, and the binder properties are varied to meet the climatic requirements of a location. EZ Street is marketed as a permanent pothole repair material for asphalt and concrete pavements.

1. Name: Instant Road Repair

2. Manufacturer:

International Roadway Research
14702 Marine Road
Humble, TX 77396
Telephone: (281) 441-3558
Fax: (281) 441-3538
www.roadwayresearch.com

3. Description:

Instant Road Repair is a rapid-curing, cold-mix patch material for asphalt and concrete pavements. The binder is a rapid-curing proprietary blend of cutback asphalt cements with polymer and antistrip agents. The aggregate is a relatively dense-graded crushed limestone.

4. Manufacturer's Provided Information:

Information on the patch material is provided in the table below.

Sieve Size	Aggregate Gradation (Percent Passing)
3/4-in.	100
1/2-in.	95-100
3/8-in.	75-100
No. 4	40-75
No. 10	8-30
No. 40	3-15
No. 80	2-10
No. 200	0-6
Binder Content (%)	4.0 – 6.5
Penetration	60-120
Ductility	100 Minimum
Stripping (Tex-530-C)	10% Maximum
Air Temperature Appl. Range	-5 °C (-40 °F) to 75 °C (168 °F)
Approximate Compacted Yield	60 kg/m ² per 2.5 cm (110 lb/yd ² per 1 in.)

Application Conditions:

The area to be patched can be wet, but it should be free of loose debris and standing water. A prime or tack coat should not be used. The minimum depth of patch should be about 25 mm (1 in.), with a maximum compacted layer thickness of 75 mm (3 in.). Thicker layers should be placed in approximately 50-mm (2-in.) thick lifts. No curing time is required—just mound material and compact with traffic. In areas with heavier loads or high tire pressures (i.e., airfield pavements), a vibratory plate compactor is recommended.

5. Physiographic Factors:

The standard packaging of the patch material is in 22.7-kg (50-lb) pails (36 pails per pallet and 23 pallets per truck load). Containers of the patch material may be stored outdoors in extreme temperatures, but should be covered for long-term storage. To better facilitate placement, the patching material should be allowed to warm as high above freezing as possible, without directly heating the material (i.e., to normal room temperature). The shelf life in sealed containers is 1 year, with longer periods possible when they are stored at moderate levels of temperature and humidity.

The cost of a 22.7-kg (50-lb) pail of Instant Road Repair is \$15.50 FOB Humble, TX. The binder material can also be purchased for use with suitable local aggregates.

6. Discussion and Recommendations:

Instant Road Repair is widely used throughout the United States and in several other countries. The material is manufactured in Texas, and the proprietary binder properties allow for this product to be used successfully in any geographical region. Instant Road Repair is marketed as a permanent pothole repair material for any asphalt or concrete pavement.

1. Name: Optimix**2. Manufacturer:**

Optimix, Inc.
535 Broadhollow Road, Suite B43
Melville, NY 11747
Telephone: (631) 249-4151 or (516) 293-6300
Fax: (516) 293-6317

3. Description:

Optimix is a cold-mix binder of patch material for asphalt and concrete pavements. The Optimix liquid asphalt blend is a proprietary blend of cutback asphalt cement with various antistrip and high-adhesion additives. An open-graded, high-quality, locally available aggregate is required for blending with the binder.

4. Manufacturer's Provided Information:

Information on the patch material is provided in the table below.

Sieve Size	Aggregate Gradation (Percent Passing)
3/4-in.	100
1/2-in.	100
3/8-in.	90-100
No. 4	20-55
No. 8	5-30
No. 16	0-10
No. 50	0-5
No. 200	0-2
Penetration	200 Minimum
Ductility	85 Minimum
Flash Point (ASTM C 92)	94 °C (200 °F)
Viscosity (ASTM D 2170)	350-3000 cSt @ 60 °C (140 °F)
Viscosity (ASTM D 2171)	115-440 poises @ 60 °C (140 °F)
Air Temperature Appl. Range	-32 °C (-25 °F) to 71 °C (160 °F)
Approximate Compacted Yield	60 kg/m ² per 2.5 cm (110 lb/yd ² per 1 in.)

Mixture Preparation:

The maximum mixing temperature of the Optimix liquid binder and the local aggregates should be between 60 °C (140 °F) and 77 °C (170 °F). The combined mixture should be stockpiled in up to 1.8-m (6-ft) depths until it has reached ambient temperature for at least 48 hr; then, it can be effectively maintained in uncovered stockpiles of 100 tons or more.

Application Conditions:

The area to be patched can be wet but should be free of loose debris and standing water. A prime or tack coat should not be used. The minimum depth of patch should be about 25 mm (1 in.), with a maximum compacted layer thickness of 75 mm (3 in.). Thicker layers should be placed in approximately 50-mm (2-in.)-thick lifts. No curing time is required—mound material and compact with traffic. In areas with heavier loads or high tire pressures, (i.e., airfield pavements), a vibratory plate compactor is recommended.

5. Physiographic Factors:

The binder is shipped from an Optimix terminal in standard asphalt tankers. The binder material must be kept at temperatures not exceeding 149 °C (300 °F), but should be covered for long-term storage. The Optimix liquid binder can be stored at ambient temperatures until it is gradually heated to the desired mixing temperature. The shelf life of the Optimix binder is 6 months, without any separation. To better facilitate placement (improve workability), the patching material should be allowed to warm as high above freezing as possible, without directly heating the mixture (i.e., to normal room temperature). The shelf life of the Optimix cold patch material is more than 1 year in a large stockpile.

The cost of the Optimix liquid asphalt blend varies with the location of the project in relation to the blending terminal. The total cost of the patching material is dependent on the binder cost and that of suitable local aggregates. The average cost of the Optimix mixture ranges from about \$55 to \$65/ton FOB from the producer's stockpile.

6. Discussion and Recommendations:

Optimix is widely used throughout the United States, including Alaska. The properties of the Optimix liquid asphalt blend are varied to meet requirements in that geographical region. Optimix is marketed as a permanent pothole repair material for any asphalt or concrete pavement.

1. Name: Perma-Patch

2. Manufacturer:

The National Paving and Contracting Company
4200 Menlo Drive
Baltimore, MD 21215-3374
Telephone: (410) 764-7117
Fax: (410) 764-7137
www.permapatch.com

3. Description:

Perma-Patch is a cold-mix patch material for asphalt and concrete pavements. The binder is a medium-curing proprietary blend of cutback asphalt cements. The binder is combined with an open-graded aggregate.

4. Manufacturer's Application Conditions:

Perma-Patch can be applied at temperatures from below -18°C to more than 38°C (0°F to 100°F). The area to be patched should be free of loose debris, but can be filled with Perma-Patch to displace standing water. A prime or tack coat is not required. The cohesiveness of Perma-Patch allows it to stick to itself without adhering to vehicle tires. The minimum depth of patch should be about 25 mm (1 in.), with a maximum compacted layer thickness of 75 mm (3 in.). Thicker layers should be placed in approximately 50-mm (2-in.) -thick lifts. No curing time is required—mound material and compact with traffic. In areas with heavier loads or high tire pressures (i.e., airfield pavements), vibratory plate compactor or standard asphalt compaction equipment is recommended for compaction. The repaired area can be opened immediately for traffic. Perma-Patch is supposed to be pressure sensitive; in other words, increased traffic, increases the rate of cure.

5. Physiographic Factors:

The standard packaging of the patch material is in 27.2-kg (60-lb) paper bags. The bags of the patch material may be stored outdoors in extreme temperatures, but must be kept dry to prevent deterioration of the bag. To better facilitate placement, the patching material should be allowed to warm as high above freezing as possible, without directly heating the material (i.e., to normal room temperature). The shelf life in sealed bags is a minimum of 1 year, with longer periods possible when they are stored at moderate levels of temperature and humidity.

The cost of a 27.2-kg (60-lb) bag of Perma-Patch should vary from \$12 to \$14 when sold and distributed through various retail outlets throughout the country.

6. Discussion and Recommendations:

Perma-Patch is widely used throughout the United States. The material is manufactured in Baltimore, and the proprietary binder's properties allow for this product to be used within any geographical region with a more open gradation being used for colder climates. Perma-Patch is marketed as a permanent pothole repair material for any asphalt or concrete pavement.

1. Name: QPR (Quality Pavement Repair)**2. Manufacturer:**

Lafarge North America, Inc.
12735 Deerfield Point, Suite 200
Alpharetta, GA 30004
Telephone: (678) 746-2233
Customer Service: (800) 388-4338
Fax: (678) 746-2238
www.qprcoldpatch.com

3. Description:

QPR is a cold-mix patch material for asphalt and concrete pavements. The binder is a proprietary modified bitumen. The aggregate is an open-graded blend of 100 percent crushed limestone or a locally available acceptable aggregate.

4. Manufacturer's Provided Information:

Information on the patch material is provided in the table below.

Sieve Size	Aggregate Gradation (Percent Passing)
3/8-in.	100
No. 4	20-55
No. 8	5-30
No. 16	0-10
No. 50	0-6
No. 200	0-2
Aggregate	
Soundness (Sodium) (ASTM C 88)	12% Maximum
LA Abrasion (ASTM C 131)	40% Maximum
Specific Gravity (ASTM C 127)	2.55 to 2.75
Absorption (ASTM C 128)	2.0% Maximum
Binder - Viscosity (ASTM D 2170)	300-4000 cSt @ 60 °C (140 °F)
Residue	
Penetration (ASTM D 5 - D 217)	180 Minimum
Ductility (ASTM D 113)	85 Minimum
Viscosity (Residue) (ASTM D 2171)	125-425 Poises @ 60 °C (140 °F)
Residue by Distillation, @ 360 °C (680 °F) Percent Original Volume (D 402)	Original Volume: 72-95
225°C (437°F)	0
260°C (500°F)	0-5
316°C (600°F)	0-25
Mixture	
Binder Content (%)	4.5 - 6.0 ¹
Flash Point (ASTM D-1310)	94 °C (200 °F)
Stripping	95% Minimum
Air Temp. Application Range	
Approximate Compacted Yield	
50 kg/m ² per 2.5 cm (90 lb/yd ² per 1 in.)	

¹ Adjusted during design, based on aggregate gradation and properties.

Mixture Preparation:

When the QPR is produced with local aggregates, the maximum temperature of the mixture should not exceed 82 °C (180 °F). The temperature of the QPR binder should not exceed 93 °C (200 °F). The QPR binder can coat wet aggregates (up to 4 percent moisture) without stripping. The QPR mixture can be placed in an outdoor, uncovered stockpile with a minimum shelf life of 1 year.

Application Conditions:

The area to be patched should be free of loose debris, but can be filled with QPR-2000 to displace some standing water. A prime or tack coat should not be used. The minimum depth of patch should be about 25 mm (1 in.), with a maximum compacted layer thickness of 75 mm (3 in.). Thicker layers should be placed in approximately 50-mm (2-in.) -thick lifts. No curing time required—mound material and compact with traffic. In areas with heavier loads or high tire pressures (i.e., airfield pavements), compact with a vibratory plate compactor or a roller.

5. Physiographic Factors:

QPR is available in 22.7-kg (50-lb) plastic bags and pails, and 208-L (340 kg) (55-gal, 750-lb) drums. The patch material may be stored outdoors in extreme temperatures in bulk piles, but the plastic bag should be kept dry to prevent deterioration of the packaging. To better facilitate placement, the patching material should be allowed to warm as high above freezing as possible, without directly heating the material (i.e., to normal room temperature). When utilizing a hot box, do not heat the QPR above 21 °C (70 °F). The shelf life of QPR in sealed containers is a minimum of 1 year, with longer periods possible when they remain sealed and are stored at moderate levels of temperature and humidity. The manufacturer guarantees the repaired area for the life of the repair or the surrounding area, or he will replace the volume of QPR at no cost.

The cost per container of QPR will vary depending on the size and type of container package and the retail outlet from which it is purchased. The price for the 22.7-kg (50-lb) plastic bags should range from \$5.25 to \$5.50, with the same material in a pail costing about \$2.50 more. The cost of QPR liquid blend varies with the location of the project in relation to the blending terminal.

6. Discussion and Recommendations:

QPR is widely used throughout the United States. The material is manufactured in Georgia, and the properties of the binder are adjusted for use in various geographical regions. QPR is marketed as a permanent pothole repair material for any asphalt or concrete pavement.

1. Name: Sylcrete EV (Extra Value Cold Mix)

2. Manufacturer:

Sylcrete Corporation
P.O. Box 413/164 Spring Street
South Salem, NY 10590
Telephone: (914) 763-5005
Fax: (914) 763-6082
E-mail: rjaxel@potholesfixed.com

3. Description:

Sylcrete EV is a cold-mix patch material for asphalt and concrete pavements. The binder is a proprietary blend of cutback asphalt cement. Sylcrete EV can be purchased with an open-graded aggregate mixture for cold weather applications or with dense-graded aggregate for warm weather applications. The Sylcrete EV binder can be obtained and combined with a locally available, high-quality crushed aggregate.

4. Manufacturer's Provided Information:

Information on the patch material is provided in the table below.

Sieve Size	Aggregate Gradation (Percent Passing)		
	No. 9 Patching ¹	No. 89 Patching ¹	Overlay ¹
1/2-in.	---	100	100
3/8-in.	100	90 – 100	85 – 100
No. 4	85 – 100	20 – 55	50 – 70
No. 8	10 – 40	5 – 30	
No. 10	---	---	32 – 42
No. 16	0 – 10	0 – 10	---
No. 30	0 – 7	0 – 7	---
No. 40	---	---	11 – 26
No. 50	0 – 5	0 – 5	
No. 80	---	---	4 – 14
No. 200	0 – 2.5	2 – 6	1 – 6
Aggregate			
Soundness (Sodium) (ASTM C 88)	12% Maximum		
LA Abrasion (ASTM C 131)	45% Maximum		
Specific Gravity (ASTM C 127)	2.45 to 2.85		
Absorption (ASTM C 128)	3.0% Maximum		
Binder - Viscosity (ASTM D 2170)	350-4000 cSt @ 60 °C (140 °F)		
Residue			
Penetration (ASTM D 5 – D 217)	180 Minimum		
Ductility (ASTM D 113)	85 Minimum		
Viscosity (Residue) (ASTM D 2171)	75-425 poises @ 60 °C (140 °F)		
Mixture			
Stripping (ASTM D 2489)	95% Minimum		
Flash Point (ASTM C 92)	94 °C (200 °F)		
Binder Content (%)	6.0 (range 4.5 to 7.0)		
Air Temperature Application Range ²	-23 °C (-10 °F) to 60 °C (140 °F)		
Approximate Compacted Yield	60 kg/m ² per 2.5 cm (110 lb/yd ² per 1 in.)		

¹ Recommended grading; ASTM D 448 or AASHTO M 43 – No. 9, No. 89, or overlay.

² The manufacture has several grades of binder based on expected climatic conditions.

Mixture Preparation:

The temperature of the Sylcrete EV binder for mixing should be within the range of 66 – 121 °C (150 – 250 °F). The locally available aggregates should be heated only if it is required to obtain a coating, and the final maximum temperature of the mixture should not exceed 80 °C (175 °F). The combined mixture should be stockpiled on a clean prepared surface of asphalt or concrete. The combined mixture should be stockpiled in depths up to 2 m (6 ft) until it has reached ambient temperature (normally about 48 hr), and then it can be effectively maintained in uncovered stockpiles of 100 tons or more.

Application Conditions:

The area to be patched can be wet but should be free of loose debris and standing water. A prime or tack coat should not be used. The minimum depth of patch should be about 25 mm (1 in.), with a maximum compacted layer thickness of 100 mm (4 in.). Thicker layers should be placed in approximately 50-mm (2-in.)-thick lifts. Generally, a 25 percent overfill should be used to account for compaction. No curing time is required—mound material and compact with traffic. In areas with heavier loads or high tire pressures, compact with a vibratory plate compactor.

5. Physiographic Factors:

The Sylcrete EV binder is shipped in bulk and must be kept at temperatures not exceeding 130 °C (265 °F). The shelf life of the uncovered Sylcrete EV cold patch material is more than 1 year when stored in stockpiles of at least 100 tons.

The cost of the Sylcrete EV binder must be obtained from the manufacturer. The total cost of the patching material is dependent on the cost of the binder and suitable local aggregates. The manufacturer guarantees a 1-year shelf life and 95 percent effectiveness in repairs.

6. Discussion and Recommendations

Sylcrete EV is widely used throughout the United States. The proprietary binder properties are varied with the climatic seasons and with the intended geographical region. Sylcrete EV is marketed as a permanent pothole repair material for any asphalt or concrete pavement.

1. Name: UPM (Unique Paving Materials)

2. Manufacturer:

Unique Paving Materials Corporation

3993 East 93rd Street

Cleveland, Ohio 44105

Telephone: (216) 441-4880, (800) 441-4880

Fax: (216) 341-8514

E-mail: sales@upm.com

www.upm.com

3. Description:

UPM is a cold-mix patch material for asphalt and concrete pavements. The binder is a proprietary blend of cutback asphalt cement and other additives. UPM can be purchased with an open-graded aggregate mixture for cold weather applications or with dense-graded aggregate for warm weather applications. The UPM binder can be obtained and combined with a locally available, high-quality crushed aggregate.

4. Manufacturer's Provided Information:

Information on the patch material is provided in the table below.

Sieve Size	Aggregate Gradation (Percent Passing)		
	Open Graded ¹	Dense Graded	
3/4-in.	---	---	100
1/2-in.	100	100	90 – 100
3/8-in.	100	90 – 100	70 – 90
No. 4	85-100	55 – 85	44 – 74
No. 8	10-40	32 – 47	10 – 25
No. 16	0-10	---	---
No. 50	0-5	5 – 15	5 – 15
No. 200		2 – 6	2 – 6
Aggregate			
Soundness (Sodium) (ASTM C 88)	12% Maximum		
LA Abrasion (ASTM C 131)	45% Maximum		
Specific Gravity (ASTM C 127)	2.45 to 2.80		
Absorption (ASTM C 128)	0.05 to 2.0% Maximum		
Soft pieces (ASTM C 123)	3.0% Maximum		
Coal and Lignite (ASTM C 295)	1.0% Maximum		
Shale, Chert, etc. (ASTM C 142)	2.5% Maximum		
Binder			
Binder Content (%)	5.0 to 6.0		
Stripping (ASTM D 2489)	95% Minimum		
Flash Point (ASTM C 92)	135 °C (275 °F)		
Viscosity (ASTM D 2170)	350-4000 cSt @ 60 °C (140 °F)		
Residue			
Penetration (ASTM D 5 – D 217)	180 Minimum		
Ductility (ASTM D 113)	100 Minimum @ 21 °C (70 °F)		
Viscosity (ASTM D 2171)	125-425 poises @ 60 °C (140 °F)		
Mixture Temp. Range for Appl. ²	10 °C (50 °F) to 60 °C (140 °F)		
Air Application Temperature Range ²	-6 °C (20 °F) to 38 °C (100 °F)		
Approximate Compacted Yield	60 kg/m ² per 2.5 cm (110 lb/yd ² per 1 in.)		
¹ Recommended grading; combination of AASHTO M 43 or ASTM D 448 – No. 9 and No. 89 or just No. 89 can also be used			
² The manufacturer has four grades of binder based on expected climatic conditions.			

Mixture Preparation:

The temperature of the UPM binder for mixing should be within the range of 66 – 121 °C (150 – 250 °F). The locally available aggregates should be heated only if it is required to obtain a coating and the final maximum temperature of the mixture should not exceed 80 °C (175 °F). The combined mixture should be stockpiled on a clean prepared surface of asphalt or concrete.

Application Conditions:

The area to be patched can be wet but should be free of loose debris and standing water. A prime or tack coat should not be used. The minimum depth of patch should be about 25 mm (1 in.), with a maximum compacted layer thickness of 100 mm (4 in.). Thicker layers should be placed in approximately 50-mm (2-in.)-thick lifts. Generally, a 25 percent overfill should be used to account for compaction. No curing time is required—mound material and compact with traffic. In areas with heavier loads or high tire pressures, compact with a vibratory plate compactor.

5. Physiographic Factors:

UPM is available in 22.7-kg (50-lb) plastic bags from various distributors throughout the United States. The bagged patch material may be stored outdoors in extreme temperatures. The shelf life in sealed bags is 1.5 years, with up to 2 years possible when they are stored at moderate levels of temperature and humidity. To better facilitate placement (improve workability), the bagged patching material should be allowed to warm as high above freezing as possible, without directly heating the material (i.e., to normal room temperature). After long-term storage, the bagged materials may be loosened by stacking them vertically for a short period of time (5 to 10 min).

The UPM binder, when used with local aggregate, is shipped in bulk. The binder material must be kept at temperatures not exceeding 130 °C (265 °F). The liquid binder could be stored at ambient temperatures, but it must be circulated during reheating. The shelf life of the uncovered UPM cold patch material is more than 1 year when stored in stockpiles of at least 100 tons. Smaller piles should be covered with a tarp to prevent contamination.

The cost of the UPM patch material in bags depends upon the source and location but will generally range from about \$7 to \$15. The cost of the UPM binder is \$0.285 per lb FOB Cleveland, OH. The total cost of the patching material is dependent on the cost of the suitable local aggregates; but it will generally range from about \$50 to \$80/ton. The manufacturer guarantees the 1-year shelf life and that repaired potholes will show significant shoving, rutting, tracking, kick-up, or raveling within 1 year of placement, with free delivery of satisfactory replacement material.

6. Discussion and Recommendations

UPM is used throughout the world, including the United States, Canada, Finland, Central America, South America, Europe, Japan, and Africa. The binder material is manufactured in Ohio and in various locations other locations throughout the United States. The proprietary binder properties are varied with the climatic seasons and with the intended geographical region. UPM is marketed as a permanent pothole repair material for any asphalt or concrete pavement.

1. Product Information: ABC Cement

2. Manufacturer: ABC Cement Corp.

3. Description: ABC is a hydraulic cement whose principal component is coal fly ash. The fly ash fraction is blended with a small fraction of poortland cement. ABC Cement also contains salts that control time of setting and rate of strength gain. By varying the content and proportions of these salts, the cement can be engineered to give a range of setting times and strengths. The following table summarizes typical properties.

Typical Properties of ABC Cement Concrete		
Property	Specific Properties of ABC Concrete Used in This Project	Range of Typical Properties of ABC Concrete
Time of setting	1 hr	1 - 6 hr
Compressive strength - 1 day	4630 psi	1,000 - 6,000 psi
Compressive strength - 28 days	9660 psi	4,000 - 10,000 psi
Tensile strength - 28 days	Not determined	300 - 500 psi
Bond strength (slant shear) - 28 days	Not determined	2,000 - 4,000 psi
Flexural strength - 28 days	600 psi	500 - 1,000 psi
Modulus of elasticity	Not determined	4 - 6 x 10 ⁶ psi
Shrinkage - 28 days of drying	0.026%	0.01 - 0.04%

The cement conforms to the requirements of ASTM C 1157 and is sold in bulk or in 5-gal buckets. The activators and retarders meeting the customer's time of setting and strength gain requirements are blended during production. The material naturally has a very low water demand, so that water reducers are not usually required. Typical water-cementitious materials ratios are 0.20 to 0.25.

4. Application Conditions: ABC Cement is proportioned by the user into either a mortar or concrete, depending on the thickness of the patching requirement. The product can also be marketed as a prepackaged material containing aggregate. All mixtures require a minimum mixing time of 7 min in order for the setting and strength regulators to dissolve. Air entraining is recommended when exposure to cycles of freezing and thawing is likely. Air contents should conform to practice for local conditions.

Minimum patch thickness is about 15 mm for mortars made with ASTM C 33 concrete sand. Minimum patch thickness for concrete patches is three times the nominal maximum size of the coarse aggregate.

Surface preparation required is typical of portland cement products. Loose material should be removed. Any surface deposits of salts should be cleaned off. The structure to be patched can be damp, but the bond surface should be dry for best bond strength performance. The patch should be cured either by moist curing or with liquid membrane-forming curing compound for at least 24 hr after placing.

1. Name: USACE Alkali-Activated Slag Concrete (AASC)

2. Manufacturer:

Concrete and Materials Branch
Geotechnical and Structures Laboratory
U.S. Army Engineer Research and Development Center
Vicksburg, MS 39180
Telephone: (601) 634-3276
Fax: (601) 634-2873

3. Description:

USACE Alkali-Activated Slag Concrete (AASC) is a mixture developed and patented by the Corps of Engineers for rapid pavement repair. The mixture can be assembled in the field from readily available materials. The mixture uses the reaction between sodium hydroxide (lye) solution and ground slag to produce a strong cementing silicate gel. Any clean aggregate can be used as the filler material. The mixture will typically set within 20 min with little evolution of heat. Hexametaphosphate (Calgon) is used as a retarding agent. The slag, alkali, hexametaphosphate and aggregate can all be shipped in a dry condition, and all of the components are stable and can be stored indefinitely when maintained in a dry condition. AASC has advantage over an accelerated portland cement-based concrete because it can be made to set faster, develop ultimate strength more quickly, has a minimum of heat generation, and can be stored for an indefinite period.

4. Manufacturer's Provided Information:

A typical mixture (with a 3-hr set time) consists of

- 100 parts by weight concrete sand (ASTM C 34 preferred)
- 100 parts by weight of ground granulated blast furnace slag (GGBFS)
(for example Aucem from Lone Star Cement)
- 6 parts by weight of sodium hydroxide
- 1 part by weight of sodium hexametaphosphate
- 40 parts by weight of water

The sodium hydroxide and sodium hexametaphosphate are dissolved in the mix water and added to the dry mix of aggregate and GGBFS. After initial mixing, water may be added to increase the workability.

Application Conditions:

The area to be patched should be wetted but free of loose debris and standing water. AASC can be mixed with any equipment that would be used to prepare a portland cement-based mixture. As with all rigid silicate-based concrete, thick patches are more durable. The mixture benefits from vibration during placing and the rate of strength gain can be increased by covering the patch and using steam to heat the material. On setting, the material typically turns dark green. Because strong alkali is involved in this patch material, personnel should be furnished chemically resistant gloves and eye protection.

5. Physiographic Factors:

All of the components required for AASC can be obtained from local suppliers in convenient-sized packages up to bulk quantities. GGBF slag is typically available from any supplier of portland cement at prices that compare with portland cement. AASC patching material is a field-assembled mixture so there is no single source, and the price will vary with location and local pricing.

6. Discussion and Recommendations

AASC is a very versatile patch material because it can be assembled locally almost anywhere in the world without delays associated with shipping a specific product from a specific manufacturing source. The use of a concentrated alkali solution makes AASC perform well with local aggregates that may not be well prepared and with less than optimum water sources. Both fresh water and seawater can be used in the formulation of AASC.

1. Name: PaveMend™

2. Manufacturer:

CeraTech
Geotechnical and Structures Laboratory
2425 Grenoble Rd.
Richmond, VA 23294
Telephone: (804) 672-7743
Fax: (804) 672-7727

3. Description:

PaveMend is intended for rapid pavement repair. The material is comprised of the following materials.

Component	CAS#
Magnesium Oxide	1309-48-4
Monopotassium Phosphate	7778-77-0
Coal Ash	N/A

As a high-early strength rapid repair material, the PaveMend products have the unique ability of providing a range of user workability prior to initial set. This range goes from 5 min of workability (suitable for anchoring), a 15-min product more suitable for spall and crater, and a 30-min material where high volume and/or extended set-time may be an issue. In all cases, PaveMend products offer the same compatibility with neighboring concrete that ensures the longevity of the repair.

4. Manufacturer's Provided Information:

Here is a table of physical properties of the different materials.

Applicable Standard C 928 for Rapid-Hardening Cementitious Materials for Concrete Repairs					
	<u>5-Min</u> (PSI)	<u>15-Min</u> (PSI)	<u>30-Min</u> (PSI)	Minimum Specs	ASTM
Compressive Strength					
• 1 hr	3330	2700	1380	N/A	C 109
• 3 hr	3830	3830	2900	1000	C 109
• 1 day (24 hr)	5060	4230	4550	3000	C 109
• 7 days	6030	5570	5330	4000	C 109
• 28 days	6100	6300	6480	≥ 7-Day Results	C 109
Bond Strength					
• 1 day (24 hr)	1970	1100	not available	1000	C 882
• 7 days	2780	2000	not available	1500	C 882
Flexural Strength					
• 7 days	700	680	620	N/A	C 78
• 28 days	930	910	860	N/A	C 78
Splitting Tensile Strength					
• 7 days	290	240	230	N/A	C 496
• 28 days	330	345	260	N/A	C 496

Scaling Resistance, lb/ft ²				
• 25 cycles	0	0	0	Max 1.0 lb/ft ³ @ 25 cyc. C 672
Modulus of Elasticity	E- 3.4 * 10 ⁻⁶	3.3 * 10 ⁻⁶	2.1 * 10 ⁻⁶	

Application Conditions:

CeraTech recommends that all users follow the American Concrete Institute's recommended practices for surface preparation of concrete to be repaired—generally sound mechanical surfaces that are clean and free of debris/residues; generally dry surface with no standing water; joints/edges squared or saw cut. Reinforcing steel should have no loose scale; no bond coat is required.

One gallon of water should be mixed with the 4 gal of volumetric material contained within each 5-gal bucket. All material should be mixed uniformly and thoroughly. A drill capable of 300 rpm's in combination with a mortar paddle mixer should be used to ensure proper mixing. Do not mix material by hand. A grout/mortar mixer can be used for large mixing volumes.

Material should be poured quickly and evenly, and spread, if needed, with a trowel or straight edge, filling voids and edges. (No additional water should be used.) No floating is necessary for smooth finish. Broom surface on initial tack if rougher texture is desired. (Perform this step quickly and uniformly.)

Clean all equipment with water immediately. Do not allow to harden.

Mixing Times, Setting Times, and Time to Allow Trafficking				
		Product		
Ambient Temp	5 min	15 min	30 min	
< 40 °F	4 min	8 min	10 min	
72 °F	3 min	6 min	8 min	
> 90 °F	2.5 min	2.5 min	5 min	
Set Times				
Initial	4 - 8 min	10 - 15 min	15 - 20 min	
Final	10 -15 min	15 - 20 min	25 -35 min	
Wheeled traffic	1.0 hr	1.5 hr	2.0 hr	

5. Physiographic Factors:

The material can be acquired from the following sources:

2425 Grenoble Rd.	806 West Diamond Ave.	1600 Wicomico St.
	Suite 200	P.O. Box 1382
Richmond, VA 23294	Gaithersburg, MD 20878	Baltimore, MD 21203
804.672.7743 Voice	301.548.7453 Voice	410.332.0633 Voice
804.672.7727 Fax	301.548.7454 Fax	410.332.0643 Fax

6. Discussion and Recommendations

The mixing time is critical. Once mixing ceases, the material hardens rapidly.

Appendix B

Concrete Repair Materials

Material Name	Use	Manufacturer	Description	Remarks
Alkali-activated slag conc. (AASC)	Patch/spall	USACE patent material	GGBFS plus sodium hydroxide + sodium hexametaphosphate	Fast set
ABC Cement	Patch/spall	ABC Cement Corp.	High early strength cement	Class C fly ash
AHT Master Hwy Patch	Patch	Master Hwy	Fast set cement	
Bonsal Vinyl PCC	Patch/spall	W.R. Bonsal		
Burke Epoxy	Patch	EDOCO, TN	2-comp epoxy	
Burke Fast Patch 928	Patch	EDOCO, TN	1-comp, cement w/ fibers and polymers	
C.G.M. Highway Patch	Patch/spall	C.G.M. Inc.		Fast-setting conc.
Chem Patch VO1 (VO2)	Patch	Chem Masters	1-comp, Polymer mod., nonshrink; (2-comp)	
Concrete Coat	Patch/spall	Euclid Chemical	2-comp., Latex Mod.	>45°F
Day-Chem Perma Patch	Patch/spall	Dayton Superior Corp.	1-component, fiber-rein.	10°F, traffic 1-hr
Delpatch (Delcrete)	Patch/spall	D.S. Brown	2-part polyurethane elastomeric Conc.	Add Agg. >45°F
D.O.T. Patch	Patch/spall	Symons Corp	1-comp, rapid set	
D.O.T. Patch HD	Patch/spall		1-comp, rapid set fibers & polymers	High Dura.
Duracal	Patch	US Gypsum Co.		
Durapatch Hiway	Patch	L&M Constr. Chemicals	1-comp., fiber-reinforced	14 min, >50 °F
Dura Patch MMA-M	Patch	Chem Masters	3-comp, methyl-methacrylate	
DuralFlex FastPatch	Patch/spall	Tamms Indus.	3-comp. epoxy	>40 °F
Dural Patch	Patch/spall	Dural Inter.	2-comp. epoxy	
Dur-o-wal CP-20	Patch/spall	Dur-o-wal Inc.		Fast-setting conc.
EMACO 2020		ChemRex, Inc.		
EMACO 415	Patch	ChemRex, Inc. ; A.H. Harris and Sons, Inc.		19 min
Eucopatch	Thin patch	Euclid Chemical	1-component	<10 min
Eucospeed (MP)	Patch	Euclid Chemical	1-component, noncementitious	<10 min (Mag-Phos, cold temp)
Fibrecrete		Applied Polymerics	Hydrocarbon resin w/ polymer, fibers	
Fibre-Patch	Patch	Gemite Products Inc.	1-comp.	
Five Star Hwy Patch	Patch	Five Star Products, Inc.	Cementitious	very rapid
Flexolith	Patch	Tamms, IL	2-comp.	≥ 40 °F
Futura	Patch/spall	WR Meadows, Sealtight	1-comp., add water	
FX-215	Patch	Fox Industries	noncementitious	

FX-826	Patch	Fox Industries	2-comp., polymer conc.	<15 °F
FX-928	Patch	Fox Industries	1-comp., add water	15 min
GeoCement	Patch	GeoBond Inter.	2-component	15 to 45 min
Highway Patch	Patch	Five Star Prod.		
HD-50	Patch	Dayton Superior Corp.	1-comp, fiber-rein., latex-modified	10 °F, traffic 1-hr
IFSCEM 110	Patch	Amer. Stone-Mix		16 min
Instant Road Repair	Patch	Safety Lights Co.		
Lambco Fast Patch	Patch	Lambert Corp.	1-comp., polymer modified	
Magna-100	Patch	Genstar Stone Products Co.	Magnesium phosphate conc.	
Mark-103 (103.1LT)	Thin patch & spall repair	Poly-Carb	3-comp. epoxy (2-comp. 20 °F)	
Mark-108 (108.6)	Thin patch & spall repair	Poly-Carb	Acrylic latex cement	
Mark 114 (114.6)	Thin patch & spall repair	Poly-Carb	Elastomeric 3-comp. (urethane)	
Mentor #924	Patch/spall	Mentor Group	1-comp.	20 min
Mono-Patch (Sep. cold wea. Formula)	Patch/spall	Bindan Corp.	1-comp.	20 min, (≤40 °F)
Nitoflor Patchroc	Patch	Preco Industries LTD		
PaveMend	Patch/spall	CTI CeraTech	Proprietary, fly ash 1-comp., add water	15 to 30 min
PavePatch 3000	Patch/spall	CONSPEC		Ultra rapid
Percol	Patch/spall	Applied Polymerics	2-component	
Percol Elastic Cement	Patch	Percol Poly-merics, Inc.		
Perma-crete	Thin patch/spall	Perma-crete	Polymer modified PCC	Reg. curing time
Perma-Patch	Patch	Interstate Prod. Inc.	Epoxy	
Polyfast LPL	Thin patch	Dayton Superior	1-component, polymer-modified	20 min
Polypatch	Thin patch	Floorpatch	2-comp. epoxy	2 min (-40 °F-100 °F)
Pro-Highway Patch	Patch/spall	CGM, Inc., PA.	1-component PCC	
Polypatch FR	Patch/spall	US Mix Pro. Co.	PCC, fibers & proprietary admix.	15 min, ≥40 °F
Quick Set 20	Patch/spall	Unitex	PCC & proprietary admixtures	20 min/10 min-work
Rapid Patch- VR	Patch	Bonsal	1-component & water	13 min
Rapid Set Non-Shrink Grout	Thin Patch	CTS Cement Manufacturing	1-component	20 min
Rapid Set DOT Repair Mix	Patch, spalls, & overlays	CTS Cement Manufacturing	1-component	20 mi
Re-Crete 20	Thin Patch	Dayton Superior	1-component	10 min
Resurf SF	Patch	Polymer Conc.	3-comp.	15 min
Roadpatch DOT	Patching, spall repair	ChemRex	1-comp., fiber-rein., cement	?? min, ≥40 °F
Rohalith Quick Patch	Patch	Sivento, Inc.		
Sealtight Futura	Patch	W.R. Meadows	1-component	
Speed Crete 2028	Patch/spall	Tamms Indus.	Cement, Proprietary additive, & water	15 min
Set 45	Thin patch, spall repair	ChemRex	1-component, concrete (add water)	15 min
SILSPEC 900 PNS	Patch/spall	SSI Const. & Indus. Matls	Elastomeric conc.	
Sikadur 22 Lo-Mod		Sika Corp.	Epoxy polymer concrete	
SikaTop 123 Plus	Thin patch	Sika	2-component, polymer-modified	15 min
Sikaset Roadway Patch (2000)	Patch/spall	Sika	1-comp. with high alumina cement (not gypsum-based)	15-25 min (15 min)
SILKIAL	Spall repair		Polymer conc.	Used by Army
Silspec 900	Patch/spall	Silicone Specialties, Inc	2-comp. liquid poly.	Rapid cure

Sonocrete Road Patch	Patching, spall repair	ChemRex	1-component, concrete (add water)	10 min
Sonocrete Sonopatch 100, without polymer	Thin patch	ChemRex	2-component	15 min
Speed Crete 2028	Thin patch	Tamms Industries	1-comp. cement with additives	25 min
<i>Swift Crete</i>		ISG Resources	2-comp., powder and activator liquid	
Techonite	Thin patch	Tectonics International	1-component, magnesium oxyphosphate cement	10 min Polymeric cement
Thermofix	Patch	Crafco, Inc.	Resin-concrete	
ThoRoc SP20 Spray Mortar	Thin patch	ChemRex	1-component, fiber-reinforced, sprayable (contains silica fume)	45 min
TechCrete (Type TBR)	Spall	Crafco Inc.	Hot-applied polymer mod. resin	Contains glass fibers
ThoRoc All-Crete 20	Thin patch	ChemRex	1-component	10 min
ThoRoc 10-60 Rapid Cement	Patch/spall	ChemRex	1-component, add water	15 min, $\geq 40^{\circ}\text{F}$
ThoRoc 10-61 Rapid Cement	Patch/spall, hot weather	ChemRex	1-component, add water	15 min, $\geq 50^{\circ}\text{F}$
ThoRoc Traffic-guard EP-35	Patch/spall	ChemRex	Epoxy polymer concrete	
Transpatch	Patch/spall	US Mix Pro. Co.	PCC & proprietary admixtures	10 min, $\geq 40^{\circ}\text{F}$
Transpo T-17	Patch/spall	Transpo Indus.	Methyl-methacrylate 2-comp,	14 – 100 $^{\circ}\text{F}$
US Spec Hwy Patch	Patch	US Mix Products Co.		
Wabo ElastoPatch	Spall	Watson Bowman Assoc.	2-comp. polyurethane	$\geq 40^{\circ}\text{F}$
Wabocrete (II)	Patch/spall	Watson Bowman Assoc.	Elastomeric Conc.	
Z-Crete	Patch/spall	Polymer Specialties Corp	1-comp., polymer, silica fume	Traffic 1 hr

Appendix C

Asphalt Repair Materials

Material Name	Use	Manufacturer	Description	Remarks
Bond-X	Pothole patch	Seaboard Asphalt Products, MD	Cutback	
Cold Patch	Pothole patch	Matrex Co.	Cutback	
DuraPave	Pothole patch	DuraPave, Inc.		Made with recycled AC
Elasti-Patch+	Pothole patch	Koch Materials	Cutback	Polymer-mod AC
ENVIROPATCH	Pothole patch	Vulcan Matl. Co.	Inverted emulsion	Open or dense graded
EZ Pave	Cold overlay	Matrex Co.	Emulsion	
EZ Street	Pothole	E-Z Street Co.	Cutback	Poly-mod.
Fibrescreed RC100A	Pothole	Prismo, LTD	Fibrous, poly. mod. AC	
Fiber Shield	Pothole	Global Solutions	Liquid polyurea	
Flex-E Shingle Mix	Pothole	Comm Recycling Systems	AC, shingles, & recy. agg.	
Hei-Way (HGP)				Latex modified
Instant Road Repair	Pothole patch	Roadway Research Inter.	Proprietary (cutback)	
Jack's Patch	Pothole patch	Comm Recycling Systems	AC, shingles, & recy. agg.	
Latexite Super Patch		Dalton Enterprises, Inc.		
Mac Patch CM-300	Pothole patch	Suit-Kote S.E., Inc.		For winter patching
Matrex, Cold Patch	Pothole patch	Matrex Co., Canada	Cutback	Supply AC and agg. gradation
Mono-Patch (Sep. cold wea. Formula)	Pothole patch	Bindan Corp.	One-comp.	20 min, ($\leq 40^{\circ}\text{F}$)
Optimix	Pothole patch	Optimix Inc.	Cutback	
Par Patch	Pothole patch	P.L.M. Corp.		All weather cond.
PatchMaster		Seal Master		
Percol Elastic Cement	Patch	Percol Polymeric, Inc.		
Perfromac HP-2 (HP-4)		Marathon Ashland Pet.		
Perma-Patch	Pothole patch	National Paving and Contracting	Cutback	SHRP H-105, SHRP-H-353
PermaPave		Neyra Indus. Inc.		
Polypatch	Pothole patch	Crafco, Inc.	Poly mod AC	
PolyPave		West Emul, Sub. of Ergon	Poly mod AC antistrip	

Qual Pvt Repa QPR-2000	Pothole patch	U.S. PRO-TEC, Inc.	Cutback	NJ, SHRP H-105, SHRP-H-353
R & R Shingle Mix	Pothole patch	Comm Recycling Systems	AC, shingles, & recy. agg.	
Ready Road Repair	Pothole patch	Ready Road Repair Inc.		
Repave	Pothole patch	Envir. Manu. Inc., Gardner AC	25% roofing	
Road Flex	Pothole patch	Road Techs, Inc.	Polymer & fillers	
Road Patch	Pothole patch	Road Techs, Inc.	Polymer & fibers	Hot applied
Sakrete Blacktop Patch		US Mix Products Co.		
Sakrete	Pothole patch	American Stone Mix, Inc.		
Star Sure-Flex	Patch/sealer	Star Inc., OH	Rubberized AC emulsion	
Sylcrete EV	Pothole patch	Sylcrete Corp.	Proprietary liquid asphalt	Workable -10 °F
Sylvax	Pothole patch	Sylvax Corp.		
Tag 8000	Pothole patch	Infratech Polymer, British Columbia	Emulsion	
Tough Patch	Pothole patch	A & E Services		Recy. AC matl.
Traffix	Pothole patch	PACE Prod., Inc.		
UPM	Pothole patch	Unique Paving Matls. Inc.	Cutback + additives	Open or dense graded

REPORT DOCUMENTATION PAGEForm Approved
OMB No. 0704-0188

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1. REPORT DATE (DD-MM-YYYY) March 2005		2. REPORT TYPE Final report		3. DATES COVERED (From - To)	
4. TITLE AND SUBTITLE Expedient Repair Materials for Roadway Pavements				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) James E. Shoenberger, Wayne D. Hodo, Charles A. Weiss, Jr., Philip G. Malone, and Toy S. Poole				5d. PROJECT NUMBER AT40	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Geotechnical and Structures Laboratory U.S. Army Engineer Research and Development Center 3909 Halls Ferry Road, Vicksburg, MS 39180-6199				8. PERFORMING ORGANIZATION REPORT NUMBER ERDC/GSL TR-05-7	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army Corps of Engineers Washington, DC 20314-1000				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT <p>Materials for expedient roadway pavement repairs must provide a trafficable repair in a minimal amount of time. Therefore, any repair material must be able to cure quickly and be easy to use.</p> <p>There are a large number of proprietary cementitious rapid repair materials for both asphalt and concrete pavements. Three types of cementitious materials were used to make acceptable expedient repairs to an asphalt roadway. Trafficking showed that these materials were not flexible enough to provide durable repairs to flexible pavements in hot weather.</p> <p>There are a number of proprietary asphalt based repair materials. These materials can generally be trafficked immediately after placement with some displacement, depending upon the loads. These products will gain more stability with time and with cooler temperatures. Repair materials using cut-back asphalts generally provide the best combination of workability and long-term storage under adverse conditions, particularly freezing temperatures. This study evaluated the asphalt repair materials for workability, strength using Marshall stability and triaxial testing, and durability in regards to cohesion and adhesion properties. The majority of repair materials use an open-graded mixture and the Marshall stability test is not appropriate for this type of gradation. The proprietary cold mixtures were all easier to apply and work with than the conventional cold mix. The products that advertised placement into wet holes all preformed well and provided equal performance in both wet and dry holes for the traffic and evaluation period used.</p>					
15. SUBJECT TERMS Asphalt cold patch Expedient repair materials Cold patch Fast-setting concrete					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES 84	19a. NAME OF RESPONSIBLE PERSON
a. REPORT UNCLASSIFIED	b. ABSTRACT UNCLASSIFIED	c. THIS PAGE UNCLASSIFIED			19b. TELEPHONE NUMBER (include area code)